AERONAUTICS

ELEVENTH ANNUAL REPORT

OF THE

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

1925

INCLUDING TECHNICAL REPORTS
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LETTER OF SUBMITTAL

To the Congress of the United States:

In compliance with the provisions of the act of March 3, 1915, establishing the National Advisory Committee for Aeronautics, I submit herewith the eleventh annual report of the committee for the fiscal year ended June 30, 1925.

The statement of the present status of aviation, as outlined in Part V of the committee's report, should dispel the impression that America is lagging in the technical development of aircraft for military purposes. Scientific research on the fundamental problems of flight and the collection of results of research conducted in other progressive nations are official duties of the committee. Their opinion that America is at least abreast of other nations in the technical development of aircraft is commended to the Congress as the most authoritative that can be had. I agree with the committee that substantial progress in aeronautics is dependent largely upon scientific research. I believe that the work of the committee is the most fundamental activity of the Government in connection with the development of aeronautics and that its continuance is essential if America is to maintain its present advanced position in aircraft development.

The condition of the aircraft industry and the prospects for the development of commercial aviation on a sound basis have materially improved during the past year. To encourage the development of commercial aviation I wish especially to indorse the recommendation of the committee for the creation of a Bureau of Air Navigation in the Department of Commerce.

Calvin Coolidge.

The White House,
December 10, 1925.

LETTER OF TRANSMITTAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
Washington, D. C., November 21, 1925.

MR. PRESIDENT:

In compliance with the provisions of the act of Congress approved March 3, 1915 (Public No. 271, 63d Cong.), I have the honor to transmit herewith the Eleventh Annual Report of the National Advisory Committee for Aeronautics for the fiscal year ended June 30, 1925.

During the past year gratifying progress has been made in improving the performance and reliability of aircraft, and the committee's program of continuous scientific research gives promise of maintaining America's advanced position among progressive nations in the technical development of aircraft for military purposes.

Public interest in aeronautics has greatly increased; and confidence in the ultimate success of commercial aviation in America on a sound basis is warranted. A beginning has been made by the letting of contracts by the Post Office Department for air transportation of the mails. In order, however, to hasten the development of commercial aviation on a broad scale, a bureau of air navigation should be created in the Department of Commerce with broad powers.

The condition of the aircraft industry has been substantially improved by the greater volume of Government orders. With sustained Government business and with the prospect of a growing commercial demand for aircraft, the condition of the aircraft industry may be regarded as no longer acute.

While these factors are encouraging and indicate progress toward a healthy development of commercial aviation on a sound basis, the committee desires to emphasize the importance of the scientific work of this committee as the most fundamental activity of the Government in connection with the development of aeronautics, from both a commercial and a military standpoint.

Respectfully submitted.

CHARLES D. WALCOTT,
Chairman.

The PRESIDENT,
The White House,
Washington, D. C.

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EXECUTIVE COMMITTEE

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DAVID W. TAYLOR, *Secretary*.

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CHARLES D. WALCOTT.
ORVILLE WRIGHT.

GEORGE W. LEWIS, *Director of Aeronautical Research*.
JOHN F. VICTORY, *Assistant Secretary*.

ELEVENTH ANNUAL REPORT

OF THE

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON, D. C., *November 18, 1925.*

To the Congress:

In accordance with the provision of the act of Congress approved March 3, 1915, establishing the National Advisory Committee for Aeronautics, the committee submits herewith its eleventh annual report for the fiscal year 1925. Final approval of the committee was given to this report on November 10, 1925. In this report the committee has described its organization; its general activities during the past year; the progress made in the scientific study, under the cognizance of the various technical subcommittees, of the fundamental problems of aeronautics; the coordination of research work in general; the examination of aeronautical inventions; and the collection, analysis, and dissemination of scientific and technical data. This report also contains brief descriptions of the technical reports, and references to the technical notes and memorandums, issued by the committee during the past year.

A statement of expenditures for the fiscal year ended June 30, 1925, is also contained in the report.

In Part V of this report, the committee presents an outline of "The Present Status of Aviation," including references to the present state of technical development, aeronautical research in the United States and its relation to national defense, the general problem of aeronautical organization, recent progress in commercial aviation, the problem of the aircraft industry, and the general airship problem as affected by the loss of the rigid airship U. S. S. *Shenandoah.*

PART I

ORGANIZATION

FUNCTIONS OF THE COMMITTEE

The National Advisory Committee for Aeronautics was established by act of Congress approved March 3, 1915. The organic act charges the committee with the supervision and direction of the scientific study of the problems of flight with a view to their practical solution, the determination of problems which should be experimentally attacked, and their investigation and application to practical questions of aeronautics. The act also authorizes the committee to direct and conduct research and experimentation in aeronautics in such laboratory or laboratories, in whole or in part, as may be placed under its direction.

Supplementing the prescribed duties of the committee, its broad general functions may be stated as follows:

First. Under the law the committee holds itself at the service of any department or agency of the Government interested in aeronautics, for the furnishing of information or assistance in regard to scientific or technical matters relating to aeronautics, and in particular for the investigation and study of fundamental problems submitted by the War and Navy Departments with a view to their practical solution.

Second. The committee may also exercise its functions for any individual, firm, association, or corporation within the United States, provided that such individual, firm, association, or corporation defray the actual cost involved.

Third. The committee institutes research, investigation, and study of problems which, in the judgment of its members or of the members of its various subcommittees, are needful and timely for the advance of the science and art of aeronautics in its various branches.

Fourth. The committee keeps itself advised of the progress made in research and experimental work in aeronautics in all parts of the world, particularly in England, France, Italy, Germany, and Canada.

Fifth. The information thus gathered is brought to the attention of the various subcommittees for consideration in connection with the preparation of programs for research and experimental work in this country. This information is also made available promptly to the military and naval air services and other branches of the Government, and such as is not confidential is immediately released to university laboratories and aircraft manufacturers interested in the study of specific problems, and also to the public.

Sixth. The committee holds itself at the service of the President, the Congress, and the executive departments of the Government for the consideration of special problems which may be referred to it.

ORGANIZATION OF THE COMMITTEE

The committee has 12 members, appointed by the President. The law provides that the personnel of the committee shall consist of two members from the War Department, from the office in charge of military aeronautics; two members from the Navy Department, from the office in charge of naval aeronautics; a representative each of the Smithsonian Institution, the United States Weather Bureau, and the United States Bureau of Standards; and not more than five additional persons acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences. The law further provides that all members as such shall serve without compensation.

During the past year there was no change in the membership of the committee.

The entire committee meets twice a year, the annual meeting being held in October and the semiannual meeting in April. The present report includes the activities of the committee between the annual meeting held on October 16, 1924, and that held on October 22, 1925.

The organization of the committee at the close of the past year was as follows:

Charles D. Walcott, Sc. D., chairman.
David W. Taylor, D. Eng., secretary.
Joseph S. Ames, Ph. D.
George K. Burgess, Sc. D.
Maj. John F. Curry, United States Army.
William F. Durand, Ph. D.
Capt. Emory S. Land, United States Navy.
Charles F. Marvin, M. E.
Rear Admiral William A. Moffett, United States Navy.
Maj. Gen. Mason M. Patrick, United States Army.
S. W. Stratton, Sc. D.
Orville Wright, B. S.

MEETINGS OF THE ENTIRE COMMITTEE

The semiannual meeting of the entire committee was held in Washington on April 23, 1925, and the annual meeting on October 22, 1925. At these meetings the general progress in aeronautical research was reviewed and the problems which should be experimentally attacked were discussed. Administrative reports were submitted by the secretary and by the Director of the Office of Aeronautical Intelligence. Doctor Ames, chairman of the executive committee, made complete reports of the research work being conducted by the committee at the Langley Memorial Aeronautical Laboratory.

At the semiannual meeting on April 23, it was noted that that date was the tenth anniversary of the first meeting of the committee, which had been held in the office of Secretary of War Garrison on April 23, 1915. The chairman remarked that 5 of the original 12 members—namely, Messrs. Ames, Durand, Marvin, Stratton, and Walcott—were still active members of the committee. Doctor Durand then recounted some of the proceedings of the first meeting, and how the original organization was effected.

At this meeting also General Patrick outlined the present purchasing policy of the Air Service and the relation of the Government to the industry, calling attention to the improvement in the latter respect during the past three years. Admiral Moffett addressed the committee on airships and their uses, pointing out particularly the importance of the use of mooring masts in connection with airship operation. Captain Land, of the Bureau of Aeronautics, described the general construction and operation of the aircraft carrier U. S. S. *Saratoga*, pointing out on a model of the ship the plan of arrangements for handling aircraft. He also exhibited photographs showing what the British Navy is doing in the development of aircraft carriers, and photographs of the American Navy's experimental carrier, the U. S. S. *Langley*.

The day following the semiannual meeting, on invitation of Admiral Moffett, members of the committee visited the naval air station at Lakehurst, N. J., and inspected the station and the rigid airships *Shenandoah* and *Los Angeles*.

At the annual meeting Doctor Ames, chairman of the executive committee, in addition to making a comprehensive report of the progress made in the investigation of a number of research problems, emphasized the existing lack of knowledge of the characteristics of aircraft propellers. He stated that the provision of means and the devising of methods for studying the performance and characteristics of air propellers constituted the greatest need at the present time in the field of technical development. He then outlined the plans of the committee for the con struction of special propeller research equipment at its laboratory at Langley Field.

At the annual meeting the committee had as its guests Rear Admiral Mark L. Bristol, United States Navy, and Commander John H. Towers, United States Navy, former members of the committee, who had recently returned to the United States from foreign duty. The committee's technical assistant in Europe, Mr. John Jay Ide, who happened to be in Washington at the time, was also present, and he and Admiral Bristol gave interesting accounts of aeronautical activities and developments in Europe.

At the annual meeting the committee accepted an invitation from General Patrick for the members of the committee to visit the engineering division of the Air Service at McCook Field, Dayton, Ohio, to inspect the field and become directly acquainted with the various engineering activities of the station.

The election of officers was the concluding feature of the annual meeting. The present officers of the committee were elected for another year, as follows: Chairman, Dr. Charles D. Walcott; secretary, Dr. David W. Taylor; chairman executive committee, Dr. Joseph S. Ames.

THE EXECUTIVE COMMITTEE

For carrying out the work of the advisory committee the regulations provide for the election annually of an executive committee, to consist of seven members, and to include further any member of the advisory committee not otherwise a member of the executive committee but resident in or near Washington and giving his time wholly or chiefly to the special work of the committee. The present organization of the executive committee is as follows:

Joseph S. Ames, Ph. D., chairman.
David W. Taylor, D. Eng., secretary.
George K. Burgess, Sc. D.
Maj. John F. Curry, United States Army.
Capt. Emory S. Land, United States Navy.
Charles F. Marvin, M. E.
Rear Admiral William A. Moffett, United States Navy.
Maj. Gen. Mason M. Patrick, United States Army.
S. W. Stratton, Sc. D.
Charles D. Walcott, Sc. D.
Orville Wright, B. S.

The executive committee, in accordance with the general instructions of the advisory committee, exercises the functions prescribed by law for the whole committee, administers the affairs of the committee, and exercises general supervision over all its activities. The executive committee holds regular monthly meetings, and special meetings when necessary.

The executive committee has organized the necessary clerical and technical staffs for handling the work of the committee proper. General responsibility for the execution of the research program in aeronautics approved by the executive committee is vested in the director of aeronautical research, Mr. George W. Lewis. In the subdivision of general duties he has immediate charge of the scientific and technical work of the committee, being directly responsible to the chairman of the executive committee, Dr. Joseph S. Ames. The assistant secretary Mr. John F. Victory, has charge of administration and personnel matters, property, and disbursements, under the direct control of the secretary of the committee, Dr. David W. Taylor.

SUBCOMMITTEES

The executive committee has organized six standing subcommittees, divided into two classes, administrative and technical, as follows:

ADMINISTRATIVE	TECHNICAL
Governmental relations.	Aerodynamics.
Publications and intelligence.	Power plants for aircraft.
Personnel, buildings, and equipment.	Materials for aircraft.

The organization and work of the technical subcommittees are covered in the reports of those committees appearing in another part of this report. A statement of the organization and functions of the administrative subcommittees follows:

COMMITTEE ON GOVERNMENTAL RELATIONS

FUNCTIONS

1. Relations of the committee with executive departments and other branches of the Government.
2. Governmental relations with civil agencies.

ORGANIZATION

Dr. Charles D. Walcott, chairman.
Dr. David W. Taylor.
John F. Victory, secretary.

COMMITTEE ON PUBLICATIONS AND INTELLIGENCE

FUNCTIONS

1. The collection, classification, and diffusion of technical knowledge on the subject of aeronautics, including the results of research and experimental work done in all parts of the world.
2. The encouragement of the study of the subject of aeronautics in institutions of learning.
3. Supervision of the Office of Aeronautical Intelligence.
4. Supervision of the committee's foreign office in Paris.
5. The collection and preparation for publication of the technical reports, technical notes, and technical memorandums of the committee.

ORGANIZATION

Dr. Joseph S. Ames, chairman.
Prof. Charles F. Marvin, vice chairman.
Miss M. M. Muller, secretary.

COMMITTEE ON PERSONNEL, BUILDINGS, AND EQUIPMENT

FUNCTIONS

1. To handle all matters relating to personnel, including the employment, promotion, discharge, and duties of all employees.
2. To consider questions referred to it and make recommendations regarding the initiation of projects concerning the erection or alteration of laboratories and offices.
3. To meet from time to time on the call of the chairman, and report its actions and recommendations to the executive committee.
4. To supervise such construction and equipment work as may be authorized by the executive committee.

ORGANIZATION

Dr. Joseph S. Ames, chairman.
Dr. David W. Taylor, vice chairman.
Prof. Charles F. Marvin.
John F. Victory, secretary.

QUARTERS FOR COMMITTEE

The headquarters of the National Advisory Committee for Aeronautics are located in the Navy Building, Seventeenth and B Streets NW., Washington, D. C., in close proximity to the Army and Navy services. The administrative office is also the headquarters of the various subcommittees and of the Office of Aeronautical Intelligence.

Field stations of the committee are the Langley Memorial Aeronautical Laboratory, at Langley Field, Hampton, Va., and the office of the technical assistant in Europe, located in Paris.

The scientific investigations authorized by the committee are not all conducted at the Langley Memorial Aeronautical Laboratory, but the facilities of other governmental laboratories and shops are utilized, as well as the laboratories connected with institutions of learning whose cooperation in the scientific study of specific problems in aeronautics has been secured.

THE LANGLEY MEMORIAL AERONAUTICAL LABORATORY

The greater part of the research work of the committee is conducted at the Langley Memorial Aeronautical Laboratory, which is located at Langley Field, Va., on a plot of ground set aside by the War Department for the use of the committee when Langley Field was originally laid out. Langley Field is one of the most important and best equipped stations of the Army Air Service, occupying about 1,650 acres and having hangar and shop facilities for the accommodation of four bombing squadrons, a service squadron, a school squadron, and an airship squadron.

In the committee's laboratory and on the flying field used in connection therewith the fundamental problems of scientific research are investigated. The laboratory is organized with five subdivisions, as follows: Power plants division, wind-tunnel division, flight test division, technical service division, and property and clerical division. The administration of the laboratory is under the immediate direction of the engineer in charge, under the general supervision of the officers of the committee.

The laboratory consists of six buildings. A research laboratory building, containing the administrative offices, the drafting room, the machine and woodworking shops, and the photographic and instrument laboratories; two aerodynamical laboratories, one containing a wind tunnel of the open type and the other a variable density wind tunnel, each unit being complete in itself; two engine dynamometer laboratories of a semipermanent type, both equipped to carry on investigations in connection with power plants for aircraft; and an airplane hangar equipped with a repair shop, dope room, and facilities for taking care of 16 or 18 airplanes.

On June 25, 1925, the committee authorized the construction of propeller research equipment large enough to investigate full-size propellers. It is expected that the propeller research equipment will be completed and in operation before the end of this fiscal year. The test chamber will be of sufficient size to accommodate the fuselage of an airplane, on which the propeller will be mounted and operated by the airplane engine. The throat of the test chamber will be 20 feet in diameter and the actual air speed will be 100 miles an hour.

Contract has been awarded for a new laboratory building known as the Service Building. Funds for the erection of this building were provided by Congress in the appropriation for 1926. The building will be located in the rear of the main research laboratory and will greatly relieve the congestion in the old building, increasing the efficiency of the organization and providing for a normal expansion for the next few years.

The research flight work was carried on with the aid of 19 airplanes, which made a total of 626 flights, approximating 245 hours' total flying time. No serious accident occurred during the year.

Recognition by the Government of the necessity of satisfying the increasing demand for new and accurate knowledge on the fundamental problems of flight has made possible the development of an efficient research organization numbering 105 employees at Langley Field at the close of the fiscal year 1925.

THE OFFICE OF AERONAUTICAL INTELLIGENCE

The Office of Aeronautical Intelligence was established in the early part of 1918 as an integral branch of the committee's activities. Its functions are the collection, classification, and diffusion of technical knowledge on the subject of aeronautics to the military and naval air services and civil agencies interested, including especially the results of research and experimental work conducted in all parts of the world. It is the officially designated Government depository for scientific and technical reports and data on aeronautics.

Promptly upon receipt, all reports are analyzed and classified, and brought to the special attention of the subcommittees having cognizance, and to the attention of other interested parties through the medium of public and confidential bulletins. Reports are duplicated where practicable, and distributed upon request. Confidential bulletins and reports are not circulated outside of governmental channels.

To efficiently handle the work of securing and exchanging reports in foreign countries, the committee maintains a technical assistant in Europe, with headquarters in Paris. It is his duty to visit personally the Government and private laboratories, centers of aeronautical information, and private individuals in England, France, Italy, Germany, and other European countries, and endeavor to secure for America not only printed matter which would in the ordinary course of events become available in this country, but more especially to secure advance information as to work in progress, and any technical data not prepared in printed form, and which would otherwise not reach this country. John Jay Ide, of New York, is the present incumbent.

The records of the office show that during the past year copies of technical reports were distributed as follows:

Committee and subcommittee members	1,113
Langley Memorial Aeronautical Laboratory	2,302
Paris office of the committee	3,428
Army Air Service	2,225
Naval Air Service, including Marine Corps	2,921
Manufacturers	3,997
Educational institutions	4,397
Bureau of Standards	1,108
Miscellaneous	14,393
Total distribution	35,884

The above figures include the distribution of 14,422 technical reports, 6,980 technical notes, and 8,006 technical memorandums of the National Advisory Committee for Aeronautics. Four thousand eight hundred and sixty written requests for reports were received during the year in addition to innumerable telephone and personal requests, and 18,939 reports were forwarded upon request.

FINANCIAL REPORT

The appropriation for the National Advisory Committee for Aeronautics for the fiscal year 1925, as carried in the independent offices appropriation act approved June 7, 1924, was $457,000, under which the committee reports expenditures and obligations during the year amounting to $437,510.62, itemized as follows:

Salaries (including engineering staff)	$177,850.89
Wages	92,341.03
Supplies and materials	16,202.08
Communication service	853.07
Travel	10,429.93
Transportation of things	1,122.30
Furnishing of electricity	8,013.15
Rent	784.74
Repairs and alterations	8,707.65
Special Investigations	33,600.00
Equipment	87,605.78
Expenditures	437,510.62
Unexpended balance	89.38
Reserves [1]	19,400.00
	457,000.00

In addition to the above, the committee had a separate appropriation of $13,000 for printing and binding, of which $10,657.50 was expended.

[1] In accordance with the practice of all Government establishments, the committee this year set up a general reserve of $10,000 for emergencies and, upon invitation of General Lord, joined the Budget Bureau's "Two Per Cent Club" which necessitated setting up $9,400 additional.

PART II

GENERAL ACTIVITIES

REVISION OF NOMENCLATURE FOR AERONAUTICS

Since aeronautics is a progressive science, the need arises from time to time for revision of its official nomenclature. Five reports on this subject have been issued by the committee; the first in 1917, the second in 1918, the third in 1919, the fourth in 1920, and the fifth, known as Report No. 157, in 1923.

In October, 1924, a special conference on aeronautical nomenclature was organized by the committee, its membership including officially designated representatives of the Army Air Service, the Bureau of Aeronautics of the Navy Department, the Bureau of Standards, the Society of Automotive Engineers, the American Society of Mechanical Engineers, and the Aeronautical Chamber of Commerce of America. As the number of terms suggested for inclusion in the official nomenclature had greatly increased since the publication of the last report on the subject, the task of revision was much greater than ever before, and to facilitate its execution the entire nomenclature was divided into four main sections and a subcommittee appointed to study and agree upon the terms for each section. These four subcommittees were as follows: Airship terms, aerodynamic terms, power-plant terms, and airway terms.

The four sections of the nomenclature, after revision by these subcommittees, were submitted to and approved by the conference as a whole, and the entire nomenclature was officially approved by the executive committee on September 19, 1925. The new nomenclature will be published in the near future as a technical report, and will supersede all previous publications of the committee on the subject.

THE THIRTEENTH WILBUR WRIGHT MEMORIAL LECTURE

Upon invitation of the Royal Aeronautical Society, Rear Admiral D. W. Taylor, U. S. N. (retired), secretary of the National Advisory Committee for Aeronautics, prepared the Thirteenth Annual Wilbur Wright Memorial Lecture, which was delivered in London, April 30, 1925, the topic being "Some Aspects of the Comparison of Model and Full Scale Tests." This paper dealt with the general question of laws of dynamic similarity and will be published by the National Advisory Committee for Aeronautics as Technical Report No. 219.

CONSIDERATION OF AERONAUTICAL INVENTIONS

Aeronautical inventions are frequently received by the committee for consideration and advice. Such inventions are examined by the committee, the necessary further correspondence is conducted with the inventors, and the inventions that give promise of being of value are brought to the attention of the Army and Navy Air Services with suitable recommendations.

A formal agreement is in effect with the Navy Department whereby aeronautical inventions of a general character which are received by the Navy Department are referred to the National Advisory Committee for Aeronautics for consideration and proper action. In such cases, when a report is made to the Navy Department a copy is sent to the Army Air Service. In a similar manner, although without formal agreement, the committee also examines inventions referred to it by the Army Air Service, and a copy of the report on any invention which appears to be promising is sent to the Navy.

ADOPTION OF STANDARD ATMOSPHERE

In response to the need for a national standard of certain basic physical constants for use in connection with aeronautical calculations relating to pressure, temperature, and density relations in a normal or standard atmosphere, the committee on aerodynamics took up the question, and, after careful consideration and agreement between representatives of the Army Air Service, the Bureau of Aeronautics of the Navy Department, the United States Weather Bureau, and the United States Bureau of Standards, recommended the adoption of a set of values, known as the standard atmosphere.

On December 2, 1924, this standard was officially approved by the executive committee, and, on recommendation of the committee, has since been adopted for use in aeronautical calculations by the War and Navy Departments, the Weather Bureau, and the Bureau of Standards.

Tables and other reference data based on this standard have been prepared by Lieut. Walter S. Diehl, of the Bureau of Aeronautics, for laboratory use, and are being published as Technical Report No. 218 of the committee, entitled "Standard Atmosphere—Tables and Data."

ADOPTION OF ALTIMETER CALIBRATION STANDARD

On suggestion of the aeronautic instruments section of the Bureau of Standards, this committee organized a special conference on altimeter calibration standards as a subcommittee of the committee on aerodynamics, for the purpose of formulating and recommending a new national standard for the calibration of altimeters. The altitude pressure relation previously in use in this country for the calibration of altimeters was based on the assumption of a constant temperature of +10° C. at all altitudes, which differed widely from the average temperatures actually experienced and hence caused altimeter readings to deviate considerably from the true altitude in many cases. It was therefore deemed desirable that a new standard be adopted which would be more nearly in agreement with actual conditions.

The special conference on altimeter calibration standards included in its membership representatives of the engineering division of the Army Air Service, the Bureau of Aeronautics of the Navy Department, the Weather Bureau, the Bureau of Standards, the National Aeronautic Association, and this committee. A meeting of the conference was held on December 6, 1924, at which the new standard was agreed upon for recommendation to the committee on aerodynamics. This standard was approved by the executive committee on February 18, 1925, on recommendation of the committee on aerodynamics, and has since been adopted by the War and Navy Departments, the Weather Bureau, and the Bureau of Standards.

STANDARD METHOD FOR DETERMINATION OF HIGH-ALTITUDE PERFORMANCE

In response to a general feeling among the organizations in this country interested, that the methods used by the Federation Aeronautique Internationale for the determination of altitudes in comparing high-altitude performance of airplanes were not sufficiently accurate, a special conference on standard method of comparing high-altitude performance was organized as a subcommittee of the committee on aerodynamics. The membership of this special conference included representatives of the Army Air Service, the Naval Bureau of Aeronautics, the Weather Bureau, the Bureau of Standards, the National Aeronautic Association, and this committee.

A meeting of this conference was held on June 3, 1925, at which a standard method for the determination of high-altitude performance of aircraft was agreed upon for recommendation to the National Aeronautic Association, which is the official representative in this country of the Federation Aeronautique Internationale. On recommendation of the committee on aerodynamics, this standard was transmitted on June 10, 1925, to the president of the National Aeronautic Association, with a view to its presentation at the annual conference of the Federation Aéronautique Internationale.

USE OF NONGOVERNMENTAL AGENCIES

The various problems on the committee's approved research programs are as a rule assigned for study by governmental agencies. In cases where the proper study of a problem requires the use of facilities not available in any governmental establishment, or requires the talents of men outside the Government service, the committee contracts directly with the institution or individual best equipped for the study of each such problem to prepare a special report on the subject. In this way the committee has marshaled the facilities of educational institutions and the services of specialists in the scientific study of the problems of flight.

STANDARDIZATION OF WIND-TUNNEL RESULTS

For the past several years tests have been conducted in various wind tunnels in this country and abroad on series of standard models with a view to bringing about a standardization of wind-tunnel results by a comparison of the results of these tests.

Three cylinder models having a length ratio of 5:1 and four models of the U. S. A. 16 airfoil having an aspect ratio of 6:0 and lengths varying from 18 to 36 inches have been tested during the past year at the Massachusetts Institute of Technology, and tests are now under way at McCook Field. These models had previously been tested at the Langley Memorial Aeronautical Laboratory, the Washington Navy Yard, and the Bureau of Standards. The tests in all the wind tunnels on these models were conducted over as wide a range of V/L as possible and included the determination of lift, drag, and pitching moment for every 4° from $-4°$ to $+20°$.

Tests have also been conducted at the request of the Aeronautical Research Committee of Great Britain on airship and airfoil models constructed by the National Physical Laboratory. During the past year a joint report on the results of the tests in this country of the National Physical Laboratory, R. A. F., 15 airfoil model has been prepared as the result of a conference between the heads of the various laboratories at which the tests were made. This report, in accordance with a recent agreement with the Aeronautical Research Committee, will probably be published in this country in the near future. An exact copy of the National Physical Laboratory airship model is undergoing test in the variable-density wind tunnel of the committee for comparison of the results with those obtained in the wind tunnels of the atmospheric type.

COOPERATION OF ARMY AND NAVY

Through the personal contact of responsible officers of the Army and Navy serving on the three standing technical subcommittees, a knowledge of the aims, purposes, and needs of each service in the field of aeronautical research is made known to the other. The cordial relations that invariably flow from such personal contact are supplemented by the technical information service of the committee's Office of Aeronautical Intelligence, which makes available the latest technical information from all parts of the world. While a healthy rivalry exists in certain respects between the Army and Navy, there is at the same time a coordination of effort in experimental engineering and a mutual understanding that is productive of the best results.

The Army and Navy Air Services have whenever called upon aided in every practicable way in the conduct of scientific investigations by the committee. Each service has placed at the disposal of the committee airplanes and engines required by the committee for research purposes. The committee desires to record its appreciation of the cooperation given by the Army and Navy Air Services, for without this cooperation the committee could not have undertaken many of the investigations that have already made for substantial progress in aircraft development. The committee desires especially to acknowledge the many courtesies extended by the Army authorities at Langley Field, where the committee's laboratories are located, and by the naval authorities at the Hampton Roads Naval Air Station.

INVESTIGATIONS UNDERTAKEN FOR THE ARMY AND THE NAVY

As a rule research programs covering fundamental problems demanding solution are prepared by the technical subcommittees and recommended to the executive committee for approval. These programs supply the problems for investigation by the Langley Memorial Aeronautical Laboratory. When, however, the Army Air Service and the Naval Bureau of Aeronautics desire special investigations to be undertaken by the committee, such investigations, upon approval by the executive committee, are added to the current research programs.

The investigations thus undertaken by the committee during the past year for the Army and the Navy may be outlined as follows:

FOR THE AIR SERVICE OF THE ARMY

Full-scale investigation of different wings on the Sperry messenger airplane.

Investigation of the behavior of an airplane in landing and in taking off.

Investigation of pressure distribution over the wing section of a VE–7 airplane.

Investigation of pressure distribution and accelerations on a pursuit type airplane.

Investigation of performance characteristics of aeromarine variable-thickness and variable-camber wing.

Acceleration readings on the PW–9 airplane.

FOR THE BUREAU OF AERONAUTICS OF THE NAVY DEPARTMENT

Investigation and development of a solid-injection type of aeronautical engine.

Development of aircraft engine supercharger.

Distribution of loading between wings of biplanes and triplanes.

Investigation of planing angles and get-away speeds of seaplanes.

Flight tests of superchargers.

Investigation of landing speed of TS airplane.

Investigation of aerodynamic loads on the U. S. S. *Los Angeles*.

Investigation of spoiler aileron control for TS airplane.

Investigation of performance characteristics of DT and CS seaplanes.

Investigation in the variable-density wind tunnel of standard propeller sections with various camber ratios.

Investigation of performance of four propellers in flight.

Investigation of water-pressure distribution on seaplane hulls.

Investigation of autorotation.

Investigation of performance of model air propellers in a free air stream and in front of VE–7 model.

Propeller tests on SC–1 airplane.

SPECIAL COMMITTEE ON DESIGN OF ARMY SEMIRIGID AIRSHIP RS–1

At the request of the Army Air Service, the National Advisory Committee for Aeronautics appointed a special subcommittee to examine and report on the design and construction of the Army semirigid airship known as the *RS–1*. This special subcommittee was organized on February 13, 1923. The five members were:

Henry Goldmark, chairman.
W. Hovgaard.
Max M. Munk.
L. B. Tuckerman.
W. Watters Pagon, secretary.

The committee met for the first time on February 23, 1923, and held 20 subsequent meetings. Four of these meetings were held at the works of the Goodyear Tire & Rubber Co.. Akron, Ohio; one at Wilbur Wright Field, Dayton, Ohio; one at Scott Field, Belleville, Ill.; one at St. Louis, Mo.; and the remainder in the office of the National Advisory Committee for Aeronautics, Washington, D. C. At practically all the meetings representatives of the engineering division of the Army Air Service and of the contractor were present and joined in the discussion.

The committee was requested to report and pass upon the design and calculations, including the method of determining the load factors and factors of safety in the design, of the *RS-1*. The committee completed its report in June, 1925, which was accepted by the executive committee and transmitted to the Chief of the Army Air Service.

The *RS-1* is a semirigid type airship, 300 feet in length, and has a capacity of 700,000 cubic feet. The triangular keel is attached with the apex pointed up and is suspended by catenary cables which are attached to three points in the keel at 10-foot intervals. The keel is constructed of aluminum alloy columns, Phoenix type, with a maximum length of 10 feet. These columns are connected by ball and socket joints in forged Lynite housings.

The *RS-1* is the first semirigid airship to be constructed in America. Of the three years spent in bringing the *RS-1* to completion, a large percentage of the time was spent in research and experimentation, which have given data of lasting importance.

One of the most important investigations was the test of a water model representing the airship, on which an elaborate series of tests was conducted by the engineering division of the Army Air Service under the direction of Professor Hovgaard. In these tests the model represented the conditions in the actual airship very closely, a wooden keel having the same relative rigidity as a full-size metallic keel being fitted to the fabric envelope.

This is believed to be the first model test of a semirigid airship in which the effect of the keel on the deflections and stresses has been taken into account. The results of the tests furnished a valuable check on the theoretical computations made by the committee.

At the meeting of the committee at Scott Field, with the *RS-1* in a practically completed condition and inflated with helium, preliminary measurements to determine the changes in the shape of the envelope and the stresses in the keel under different service conditions were made. These measurements, although of a preliminary nature, are of interest, as they seem to confirm the theoretical computations. It is understood that an extended series of measurements will be made on the airship when completed and ready to fly.

The committee devoted much time to a review of the stresses in the *RS-1*, and also made an extended study of the strength of semirigid airships generally, which is probably more complete than any previous study undertaken. In connection with this study, individual members of the committee have made analytical investigations on different points involved, which add materially to the general knowledge on this subject. The individual contributions were added to the report in the form of appendixes, including particularly discussions of the aerodynamic load, of the design of the nose cap, of breathing stresses, and of the statical longitudinal stability of semirigid airships.

AMERICAN AERONAUTICAL SAFETY CODE

The final draft of the Aeronautical Safety Code was approved by the sectional committee that is sponsored by the Bureau of Standards and the Society of Automotive Engineers (Inc.), on April 23, 1925, and was subsequently submitted to and approved by the sponsors who referred it to the American Engineering Standards Committee for final approval as a tentative American standard. The code has been prepared in printed form and may be obtained from the society.

The sectional committee is widely representative of the aeronautical interests and functions under the procedure of the American Engineering Standards Committee, the principal organizations represented on the sectional committee being the Aeronautical Chamber of Commerce, American Institute of Electrical Engineers, American Society of Mechanical Engineers, American Society for Testing Materials, American Society of Safety Engineers, Manufacturers Aircraft Association, National Aeronautic Association, National Aircraft Underwriters Association, National Advisory Committee for Aeronautics, National Safety Council, Rubber Association of America, Society of Automotive Engineers (Inc.), Underwriters' Laboratories (Inc.), United

States Bureau of Standards, United States Forest Service, United States Navy Department, United States Post Office Department, United States War Department, United States Weather Bureau.

The committee is a continuing one, subject to call by the sponsors to reconsider the code in part or as a whole whenever it may seem advisable to do so, although it is felt that such revisions should not be necessary for some time because of the care that was taken in preparing the code. It has been the objective of the committee to prepare a code that will promote general agreement and mutual understanding as to acceptable practices for safety in the construction and performance of aircraft but not to prescribe too closely the methods of design, construction, or operation. It is hoped that on this basis the code will prove to be a valuable guide to designers, constructors, and operators of both aircraft and airdromes in advancing the development of commercial aviation, and to constituted authorities in enforcing regulations that may be enacted to govern this branch of the transportation service and industries.

PART III

REPORTS OF TECHNICAL COMMITTEES

REPORT OF COMMITTEE ON AERODYNAMICS

ORGANIZATION

The committee on aerodynamics is at present composed of the following members:

Dr. Joseph S. Ames, Johns Hopkins University, chairman.
Commander H. C. Richardson, United States Navy, vice chairman.
Prof. Edward P. Warner, Massachusetts Institute of Technology, secretary.
Dr. L. J. Briggs, Bureau of Standards.
Capt. Gerald E. Brower, United States Army, engineering division, Air Service, McCook Field.
Lieut. W. S. Diehl, United States Navy.
H. N. Eaton, Bureau of Standards.
George W. Lewis, National Advisory Committee for Aeronautics (ex officio member).
Maj. Leslie MacDill, United States Army, engineering division, Air service, McCook Field.
Prof. Charles F. Marvin, Weather Bureau.
Dr. A. F. Zahm, construction department, Washington Navy Yard.

FUNCTIONS

The functions of the committee on aerodynamics are as follows:

1. To determine what problems in theoretical and experimental aerodynamics are the most important for investigation by governmental and private agencies.
2. To coordinate by counsel and suggestion the research work involved in the investigation of such problems.
3. To act as a medium for the interchange of information regarding aerodynamic investigations and developments, in progress or proposed.
4. To direct and conduct research in experimental aerodynamics in such laboratory or laboratories as may be placed either in whole or in part under its direction.
5. To meet from time to time on the call of the chairman and report its action and recommendations to the executive committee.

The committee on aerodynamics, by reason of the representation of the various organizations interested in aeronautics, is in close contact with all aerodynamical work being carried out in the United States. In this way the current work of each organization is made known to all, thus preventing duplication of effort. Also all research work is stimulated by the prompt distribution of new ideas and new results, which add greatly to the efficient conduction of aerodynamic research. The committee keeps the research workers in this country supplied with information on all European progress in aerodynamics by means of a foreign representative who is in close touch with all aeronautical activities in Europe. This direct information is supplemented by the translation and circulation of copies of the more important foreign reports and articles.

The committee on aerodynamics has direct control of the aerodynamical research conducted at Langley Field, the propeller research conducted at Stanford University under the supervision of Dr. W. F. Durand, and a number of special investigations conducted at the Bureau of

Standards. The aerodynamical investigations undertaken at the Washington Navy Yard, the engineering division of the Army Air Service at McCook Field, the Bureau of Standards, and the Massachusetts Institute of Technology are reported to the committee on aerodynamics.

LANGLEY MEMORIAL AERONAUTICAL LABORATORY

ATMOSPHERIC WIND TUNNEL RESEARCH—*Airfoils.*—Biplane and triplane lift distribution tests have been continued and the results further studied and analyzed. At low-flying speed, the air forces may be considered for all practical design purposes as equally divided among the component wings. At high-flying speed, however, and in the case of a highly maneuverable airplane the distribution of the lift follows a less simple law. This distribution depends then on the wing sections used, and even more on the geometric arrangement of the wing cellule.

The pressure distribution measurements on three thick airfoil models (N. A. C. A. 81, U. S. A. 27C mod., and U. S. A. 35) have been satisfactorily completed. The technique of testing half-span models by the use of a reflecting plane was developed in the course of these experiments. The experience gained will be of great benefit in future work. The information obtained will be valuable in both stress analysis and airfoil design.

As a further result of this research, a new thick wing section has been designed and its air forces have been measured. The results show a considerable gain in aerodynamic efficiency. Furthermore, one very undesirable property common to most tapered wings has been eliminated. Most tapered airfoils have the root section and the tip wing section parallel; occasionally the tip is washed out. This results in an airfoil with a changeable angle of zero lift along the span, and consequently, when the total lift is zero the air force on the tips is downward and that at the middle section is upward. In the new design the wing has been sufficiently washed in to bring all sections simultaneously to zero lift.

A half-span, pressure distribution model of the upper wing, aileron, and overhanging horn balance of a Fokker D-VII airplane is now awaiting test. Interest in this investigation centers around the pressures on the aileron, balance, and that portion of the wing tip which will be affected.

Model airplanes.—Models of two airplanes, one a pursuit landplane and the other a giant twin-boat seaplane, both designed by Mr. J. V. Martin, were given complete tests at the request of the select committee of inquiry into operations of the United States Air Services.

There have also been made tests with the model of a training type airplane. This investigation was one of the most interesting problems of the year. The airplane had exhibited the unusual characteristic of progressing from a normal spin into a flat one from which recovery had sometimes been impossible. Special apparatus was devised to give the model freedom in pitch while spinning in the tunnel. The tests showed that a reduction of gap, accompanied by an upward and forward shift of the center of gravity, serve to eliminate this tendency, and it is believed that under these conditions the controls would be sufficiently effective to prevent entering the flat spinning condition. On completion of the spin tests, the lift, drag, and pitching moment of the model with reduced gap were measured.

Fabric flapping.—A very important problem was an investigation relating chiefly to airship coverings. The factors which control the flapping of a rectangle of fabric supported along its edges and having only one surface exposed to tangential air flow were studied. The air speed at which flapping definitely began was observed, and the data are sufficiently indicative to show the most logical means of suppressing the phenomenon. Prevention of flapping in the covering of an airship would materially reduce the resistance to motion and increase the life of the fabric.

Rotating cylinders.—To clear up some of the questions unanswered by last year's tests, a new investigation of rotating cylinders has been conducted. The reversal of direction of the cross wind force at low-speed ratios has been explained. The air forces observed were far in excess of those of ordinary wings of similar dimensions. The tests show that the air forces on rotating cylinders can not be computed by assuming the circulation to be equal to the circulation of one cylinder's surface, as has been proposed by several authors. The shape of the cylinder ends proved of great influence on the results; end disks had a beneficial influence.

Miscellaneous.—As in the past, the tunnel has been used to calibrate and locate the aerodynamic axes of a number of instruments.

Tests of a "turbulence meter" were made and the results were used to further improve this instrument.

Technique of producing smoke and photographing filaments of the same in the air stream has been materially improved. Through the use of electrical apparatus, it is now possible to obtain these photographs with an exposure of approximately one-millionth of a second.

Variable Density Wind Tunnel—*Research on airfoils.*—A series of airfoils has been tested in the variable density wind tunnel at a high Reynolds number. These 27 sections were derived from Doctor Munk's theory of the airfoil such that the travel of the center pressure would be small. The test results showed remarkable agreement with the theory, and in particular demonstrated clearly that the coefficient of pitching moment about a point at 25 per cent of the chord is practically a constant, which is predicted by the theory. There were several good sections in this group, which show excellent characteristics (N. A. C. A. M–4, M–6, and M–12). Further work on similar airfoils is to be done in the near future.

In connection with the research on the Army Air Service (Sperry) messenger airplane, a group of airfoils of the same sections (U. S. A. 5, U. S. A. 27, U. S. A. 35A, U. S. A. 35B, R. A. F. 15, Göttingen 387, and Clark Y) were tested at five different tank pressures from a low to a high Reynolds number. Besides obtaining results comparable with full-scale conditions on these sections, information was obtained as to the variation of the airfoil characteristics with scale or Reynolds number. In general, the minimum drag coefficient decreases as the scale is increased. The maximum lift/drag ratio increases in the same manner, though to a lesser extent. The scale effect of the maximum lift coefficient differs considerably for different airfoils, and as yet no general rule can be stated as to its true scale effect.

Tests are now in progress on a series of biplane cellules, using airfoils of the R. A. F. 15 section with several gap/chord ratios.

Tunnel wall interference tests.—In making corrections for the effect of the wind tunnel walls on data from tests, there was noticed considerable discrepancy in the slope of the lift coefficient curve plotted against angle of attack of observed values compared with the theoretical. Doctor Munk is now analyzing the theoretical corrections and tests are now in progress in the tunnel to determine the experimental corrections. These tests are made with airfoils of the same section and chord, but of various aspect ratios.

A velocity survey across the tunnel close to the walls is to be made, taking into account its influence on the induced drag.

Tests of airplane models.—The United States Army Air Service (Sperry) messenger airplane model with U. S. A. 5 wings was tested at full-scale conditions as received from the engineering division, Air Service, without a propeller. In comparing the results obtained with those of free-air tests on the airplane, the minimum drag of the model was found to be low. As is the case with most atmospheric wind-tunnel models, most of the details were omitted. These were then added, with a subsequent increase of 30 per cent in the minimum drag. In both cases the propeller was omitted. The effect of a rotating propeller is known to be considerable. In further work on this research a propeller will be installed on the model and the condition of operation will be that of zero torque.

A test of a model of the Fokker D–VII was made at a Reynolds number very close to full scale and from a computed performance, remarkable agreement with that of flight tests of the full-size airplane was found.

Miscellaneous.—A new method of support for models was developed in which stream-line wires of a large size are used, both in compression for negative loading and in tension for positive loading. A decrease in tare drag of 90 per cent on the 20-atmosphere tests was obtained.

Adjustments have been made at various times to the balance apparatus, improving its operation and reliability. The air flow has been further improved by minor changes in the walls of the experimental chamber and by covering the outer cone with painted canvas.

Because of the high humidity and operating temperatures some difficulty has been encountered with the separation of the drive-propeller laminations. This was finally overcome by the use of a special glue and by covering the blades with a monel metal sheath.

FLIGHT RESEARCH—*Airships.*—During the last year the information obtained as a result of the investigation of pressure distribution on the hull and tail surfaces of a nonrigid airship has been studied, analyzed, tabulated, and submitted in report form. The data thus available cover the pressures experienced at the 400 points investigated in nearly all possible maneuvers and are of great value for design purposes, being the only material of this kind that has been obtained in any great quantity on an airship in actual flight. While the results showed that the pressures and loadings resulting from maneuvers were never in excess of those used in design computations, they indicated, however, that those experienced in bumps and gusts were probably very much larger and might exceed the design factors in use at the present time.

As a continuation and an elaboration of the tests on a nonrigid type, considerable time and work has been spent on the preparation of a research program and the construction of apparatus for pressure distribution, turning trials, and acceleration tests on a rigid type, the U. S. S. *Los Angeles.* Some preliminary acceleration tests have already been carried out on this airship, in which it was attempted to measure the accelerations produced by gusts and bumps, in conjunction with strain gauge measurements conducted by the Bureau of Aeronautics. The tests were unsuccessful, however, owing to lack of proper air conditions.

Airplanes.—The air flow about an airplane in flight has received considerable attention within the last year in connection with two flight research problems—namely, angle-of-attack measurements and investigation of ground effect. The former problem, that of obtaining accurate angle-of-attack measurements in flight, is extremely important for flight-test work because of the nearly universal use of angle of attack as a basis for comparing different results. The measurement is very difficult of attainment because of the effect of the interference of the airplane itself upon any instrument used for measuring angle of attack. A survey of the air flow about the wing structure of a biplane in flight has been conducted, which showed that a small region or zone existed where the interference on an angle-of-attack vane was negligible, and consequently an instrument mounted at this place would register angle of attack with sufficient accuracy. The second problem, ground effect, is now being investigated. It is considered that the change of performance of an airplane at an altitude and close to the ground is due to the change of air flow produced by the proximity of the ground. By means of longitudinal smoke flow over the wings and transverse patterns obtained by flying through smoke curtains, together with pressure distribution measurements along a chord of the wing, a study is being made which it is felt will provide information for estimating quantitatively the ground effect.

At the request of the Army Air Service an investigation has been conducted and completed on the landing and take-off characteristics of nine airplanes, comprising all of the service types used by the Army. The material obtained shows the air speed, acceleration, control position, and ground run of each airplane when landing and taking off. It was intended primarily for use in the instruction of student pilots, to enable them to visualize the movement of the controls, the behavior of the airplane, etc., but will also be found of value in the improvement of the landing and take-off characteristics in new design, as well as useful for estimating the proper size of proposed landing fields.

Planing tests conducted for the Bureau of Aeronautics on three representative types of seaplanes—single-float, twin-float, and boat type—have been completed. The complete planing characteristics, including air speed, water speed, angle of attack, length and time of run, etc., have been measured on each type, and a comparison of these full-scale results with similar ones obtained in model-basin tests will be made with a view to improving the methods of the latter. The results obtained are also of direct value to designers of seaplanes and seaplane floats and should be of interest and value to the service pilot in obtaining the best take-off performance of each type. Laboratory tests are now in progress on the development of a method of measuring the water-pressure distribution on a pontoon while landing, taking off, and taxiing. The maximum pressures occur as a result of the impact at landing or the impact of waves striking the hull, and the forces exist for such a short period of time that the difficulty of recording is considerable.

Because of the higher speed and greater maneuverability of present-day airplanes, the methods of load computations and loading specifications now in use are in need of revision to eliminate the possibility of failure in flight. Although considerable work has been done in the wind tunnel and in flight on pressure distribution, there is little information available on the pressures experienced during accelerated flight which is known to be applicable to modern airplanes. An investigation has been completed on two airplanes, the *VE-7* and the *TS*, in which the pressures over a rib section of the wing and tail surfaces have been measured in violent maneuvers. These pressures and loads will be used for preliminary revision of the load-computation methods now in vogue, but, as a single rib is only indicative of the loads on a complete wing, further work has been planned in which a complete investigation will be made of the pressure distribution over the wings and tail surfaces of a high-speed pursuit airplane. The apparatus and instruments for this latter research are in readiness and an airplane with special alterations to accommodate the apparatus is under construction.

Tests are now in progress on a Sperry messenger airplane equipped with six different sets of wings, the purpose of which is to determine full-scale characteristics which may be compared to the same characteristics of a model of the airplane as determined in an atmospheric and a variable density wind tunnel in order to study and if possible determine the nature and magnitude of the existing scale effect. The experiments have already indicated the necessity of a much closer duplication of the actual airplane for a model used in the variable density tunnel at high Reynolds number than for the same in the atmospheric tunnel, and has necessitated the reconstruction of the Sperry messenger model for use in the variable density tunnel. In connection with these tests a study has been made of the methods of obtaining an airplane's lift and drag characteristics in flight and a paper has been prepared and published describing the various methods, with recommendations for their use, based on the experience of the laboratory in such test work.

In order to find the variation in the wing contour of an airplane from the intended contour due to inaccuracies in construction and to the sag of the covering between the ribs of a fabric-covered wing, measurements are being made on a number of service airplanes. The information is desired principally for use in determining the accuracy necessary in model construction but will also provide data from which the comparison of the aerodynamic qualities of wings with rigid and sagging coverings may be derived.

Propellers.—The methods and apparatus for flight testing of airplane propellers developed last year have been improved upon, so that the laboratory is in position, and has been requested to do an increasing amount of this type of research. At present two propeller researches are in progress, consisting of tests of four propellers for the *VE-7* airplane and four for the *SC-1* seaplane. The former research is a continuation of last year's propeller research program, the flight tests to be compared with wind tunnel tests of similar model propellers to further establish the relation between the two, and the latter is to determine the propeller most suitable for the *SC-1* seaplane.

Performance.—Performance tests are now being conducted on DT and CS airplanes to determine the possible improvements in the performance of these airplanes equipped with Wright T-2 and T-3 engines when the use of (*a*) overcompression, (*b*) superchargers, (*c*) gears, or (*d*) combination of gears with overcompression or superchargers, is resorted to. In addition to the performance tests of complete airplanes, flight tests have been conducted on various airplane gears and apparatus which are auxiliary to the airplane. In this category were the tests of the spoiler aileron control and the aeromarine variable-camber wing. The former is a flap gear for airplanes, used to supplement the aileron control, which was designed and built by and tested for the Bureau of Aeronautics. The tests of the variable-camber wing were made at the request of the Army Air Service.

INSTRUMENT RESEARCH AND DEVELOPMENT.—The increase in flight research during the past year has made it necessary to duplicate a number of the standard instruments. Opportunity was taken, in constructing these instruments, to incorporate many improvements which were found desirable.

One of the most important pieces of instrumental equipment completed this year was the altitude chamber. In this apparatus an instrument may be subjected to the same pressures and temperatures as those experienced at altitudes, ranging from ground level to over 40,000 feet. It was developed for the purpose of studying the effect of low temperatures and pressures on our various recording instruments with a view to the elimination of errors resulting from the effect. The design of the apparatus is such that it is convenient to operate, is absolutely safe, and requires the minimum of time for making the necessary investigations.

A new type of flight-path air-speed recorder was developed and put into operation. This instrument is used for simultaneous recording of the flight-path angle and the air speed of an airplane, and is far superior to previous models in that its charts are more easily renewed, it is easily installed in various airplanes, has greater accuracy, and is more reliable in operation. The 60-capsule recording manometers under development during the past year for use on airship investigations have been completed but are now being adapted for pressure-distribution tests on the Boeing pursuit airplane. A suspension-type galvanometer has been completed by the Bureau of Standards and will be used in connection with the measurement of control forces. For use in the calibration of altitude instruments a new motor-driven micromanometer has been developed which affords greater accuracy, is more convenient, and reduces the time required for calibrations.

Of the more important instruments under development or construction those described below are typical. There is now being assembled an instrument for recording the air speed and altitude, having a mechanism arranged for many traverses of the altitude chart, resulting in a recorder combining extreme sensitivity with large range. This instrument should prove of value for very accurate determinations of the height of airplanes at high altitudes. An instrument which will prove of value in both the flight research and power plants work is a temperature-revolutions-per-minute recorder. This will combine in one instrument recording on one chart an electric-resistance type thermometer and an electric-type tachometer. For power plant use a fuel-flow recorder is being developed. This instrument will make use of the difference in pressure of a fluid passing through various sections of a Venturi, and will fill an important need in the investigation of engine characteristics during flight. For the more accurate calibration of accelerometers and turn recorders, as well as the study of means of damping for such instruments, a calibrating fixture is being developed. This apparatus will reduce the time required for making such calibrations and also allow the study of proper damping of accelerometers and turn recorders. A model is now being constructed to show the effect of a rotating cylinder in an air stream and will effectively demonstrate the principle of the Flettner rotor.

At the Bureau of Standards an electric-driven turn recorder is being developed along the lines of our standard recording instruments, a three-component galvanometer is being designed, and a very accurate thermometer of the resistance type is being constructed for use at low temperatures, such as are experienced at high altitudes.

Perhaps the most important investigation carried on during the year has been the study of pressure lag and depreciation in tubing. This work was carried on for the purpose of determining the most suitable lengths and sizes of tubing to be used with recording instruments in connection with the study of pressure distribution on aircraft. A complete investigation was made to determine the lag in pressure through long tubes and the reduction or increase in pressure at the far end of such tubes. Much data have been obtained which will allow the use of the proper size and length of tubing in connection with many of our pressure-distribution researches and insure the maximum accuracy of results. A careful study has been made of the temperature effect upon our standard pressure capsules and from this investigation methods of assembly and adjustment have been devised which almost entirely eliminate temperature effect upon these important components of our pressure-recording instruments.

All of these investigations have required special apparatus which has been designed and constructed at the Langley Memorial Aeronautical Laboratory. A Bendemann hub dynamometer which has been received from the Navy Department has been thoroughly investigated, tested, and found satisfactory for use in connection with the flight test of power plants. In connection with some of our wind-tunnel problems the instrument section has developed a method for making very accurate models of propellers. These model propellers are made entirely from metal and are an exact duplicate, except as to size, of the large propellers from which the measurements were taken. The use of these small model propellers in connection with model tests in the variable density wind tunnel will help increase the accuracy of comparison between model tests and full-scale research.

The National Advisory Committee for Aeronautics has cooperated with both the Army and Navy in supplying special recording instruments for various flight problems. At the request of the Bureau of Aeronautics the committee has supplied the Navy with accelerometers and instructed their personnel in their operation for studying the characteristics of the catapult and landing gear on the U. S. S. *Langley* and at the Naval Aircraft Factory in connection with the strength requirements for airplanes.

AERODYNAMIC THEORY

Last year's progress in fundamental aerodynamic theory has been substantiated throughout the present year. Its application to practice has been demonstrated, and further light thrown on its derivation and on its relation to other branches of technical mechanics.

All experiments made to check the important theory were successful and show very good agreement. Within the useful range of angle of attack of an airfoil, the lift and air force moment computed agree in a very satisfactory way with the values observed in experiments.

The theory was used to lay down a series of wing sections all distinguished from ordinary wing sections by a characteristic of great practical value, viz, the absence of travel of the center of pressure. Not only did the wind-tunnel tests confirm this anticipated stability of the wing section, but some of these sections (notably, M-6) also proved to be good wing sections in respects other than stability, so that the new theory has directly led to an improvement of wing section design.

Theory has been advanced in several minor respects. Several tables of important numerical values have been computed and published. Some of these tables are required for the actual application of the airship hull theory and of the wing theory, and give the numerical values of aerodynamic inertia factors. An elaborate investigation refers to pressure distribution tests and gives rules for the distribution of pressure orifices and to compute conveniently the air forces from observations. Standard conditions of the atmosphere have been established to make free flight observations comparable in all cases. Further progress has also been made to improve the interpretation of wind-tunnel experiences. The wind tunnel continues to be the main source of experimental information in aerodynamics, and new insight has been obtained on how to construct the models and how to take care of the influence of the tunnel dimensions on the result.

The variable-density wind tunnel has so far substantiated expectations and has not yet shown any indication of scale effect at tests made at full Reynolds number.

It is expected that the next year will bring further steady progress along all these lines. Furthermore, the fundamental theory will be expanded and worked out in detail to cover a larger portion of the problems and in order to forecast more aerodynamic properties. The first problem to be attacked will be the computation of the pressure distribution over a wing section, and further progress in the wind-tunnel technique is expected.

STANFORD UNIVERSITY

During the year the staff of the aerodynamic laboratory has been occupied in the preparation of four reports based on research and observation work carried on for the most part during the preceding year and noted in the report for 1924. These researches by name are as follows:

(1) Loss of propulsive efficiency due to operation of air propellers forward of obstructions representing actual airplane structures.

(2) Tests of 13 Navy type propellers.

(3) Tests of 30 model propellers for Army Air Service, engineering division, McCook Field.

(4) Tests of five Navy type model propellers in connection with a model representing the mid-structural part of the Vought airplane and carried out in parallel with tests on the actual airplane in flight, conducted at Langley Field.

The reports of these investigations have been completed and numbers (1), (2), and (4) have been placed in the hands of the committee for examination and publication.

The laboratory is just now beginning two new researches as follows:

1. Tests on a group of metal air-propeller models with adjustable blades and representing 31 different propellers. These tests are to be carried out for the Army Air Service, engineering division, at McCook Field.

2. Tests on the Vought airplane model, as in research (4) referred to above, and in combination with three metal air-propeller models.

In addition, windmill and propeller brake tests have been carried out on a three-bladed model propeller form.

During the year some refinements and minor changes, as indicated by experience, have been made in the propeller dynamometer and instrumental equipment of the laboratory.

WASHINGTON NAVY YARD

Airfoils and wings.—Tests have been made during the past year on 31 models of airfoils and airplane wings. These models include both routine design testing and research. Among the research tests were a series of six airfoils in which the effect of various forms of cut-outs in the center of the span was investigated, the results indicating that the conventional form is probably the most satisfactory aerodynamically. Other research investigations on airfoils included five models with trailing edge flaps.

The study of modifications of standard airfoils is being further extended along the lines previously followed. The immediate purpose of this study is to improve the structural characteristics of certain thin but very efficient sections without seriously affecting their high efficiency.

Control surfaces.—Thirteen model-control surfaces have been tested during the past year. Of these models, eight were tested for design purposes, chiefly to study the effect of plan form, and the remaining models were divided between two research investigations.

A research was made to obtain data on three forms of trailing edge flaps suitable for reducing the landing speed as well as supplying lateral control. The results show that the combination is quite feasible, but that further tests are desirable to develop a better type of flap.

A research on the so-called "dead-center effect" has been partially completed. Pilots have reported the existence on certain airplanes of an angular range about the neutral position, particularly for elevators, for which there was no response to control movements. This research has been laid out to investigate the relation between control angle and controlling force for small angles for six types of controls. Data so far obtained do not indicate any unusual action, the lifting force varying linearly with control angle at and near the neutral position.

Airplane parts.—Testing on the series of fuselage models, long delayed by more urgent work, is now under way. As previously explained, this series consists of 10 models representative of Navy designs.

Comparative tests have been made on two full-scale radiators, one a conventional tubular free-air type, the other a Heinrich stream line fin type. The Heinrich type was found to compare very favorably with the conventional type.

Tests have been completed on two model flying-boat hulls which differed mainly in the fineness of the lines aft. The model with the finer lines had appreciably less resistance in both air and water.

Airplane models.—Routine tests have been made on 10 airplane models during the past year. Most of these models were tested in both land planes and sea plane arrangements and one model was tested with three wing sections. In all, 19 complete routine tests were made.

An unusually extensive investigation was made on the models of the *NB-1* in order to investigate the flat spin peculiar to this type. These tests over the full range of 360° in angle of attack with and without tail surfaces.

There has been a very pronounced tendency to extend the range covered by routine tests. It is estimated that a routine test on an airplane model at the Washington Navy Yard now requires approximately ten times the number of readings taken in a similar test five years ago. However, owing to the improvements which have been made in the testing technique, a routine test now requires considerably less time than it formerly did.

In connection with the routine testing of current airplane designs there are two features of general interest. In 1921 the Navy adopted the method of calculating a correction for all minor parts such as struts, wires, and fittings. Since that time the test data have been uniformly reliable and their use in predicting performance has been very satisfactory. The second feature is the rapidity with which test data are made available to the designer. In order to avoid the delay incident to the preparation of a formal report, a photostatic copy of all test data is forwarded to the Bureau of Aeronautics immediately upon the completion of a test, and becomes available to the designers without further delay.

Miscellaneous tests.—Tests have been made on four full-size target sleeves, two being of the conventional cone type and two of a new stream-line type.

A very extensive series of standardization tests on airfoils and cylinders has been completed on the N. A. C. A. models.

In the course of a study of vibration of tail surfaces in certain types of airplanes a series of tests which shed considerable light on the fundamental causes of vibration and flutter were made. The report on these tests should be of interest to all engineers.

Three tests have been made on the fairing of a nacelle into the upper surface of the lower wing of a biplane. These tests indicate the necessity for a generous fillet if it is desired to reduce interference to a reasonable value.

Calibration tests have been made on 12 Pitot-Venturi tubes and the characteristics of one tube were determined over a wide range of angle in pitch and yaw. A research investigation is now under way to develop a reliable tube which can be made at a low cost.

Lighter than air.—Testing on lighter-than-air models during the past year has been confined to a series of tests on the C-class airship in pitch and yaw with two types of control surfaces. Several projects are now on hand awaiting completion of more urgent work. These tests include damping coefficients on three models and resistance tests on the car of a rigid airship.

BUREAU OF STANDARDS

Wind-tunnel investigations.—The aerodynamical work of the Bureau of Standards during the past year has been carried on in part in the three wind tunnels in Washington and in part, through the courtesy of the Chemical Warfare Service, at the large compressor plant at Edgewood Arsenal. The wind tunnels at the Bureau are 3, 4½, and 10 feet in diameter and have speed ranges of 11 to 150 miles per hour, 17 to 90 miles per hour, and 10 to 70 miles per hour, respectively. The compressor plant at Edgewood is capable of delivering 2,000 cubic feet of free air per minute at any desired pressure up to 100 lbs./in.^{2}

Further studies of expanding nozzles have been made at Edgewood in cooperation with the Ordnance Department of the Army with a view to securing an air stream suitable for measuring the resistance of model projectiles at speeds above the speed of sound. For speeds up to approximately 1.15 times the speed of sound, expanding nozzles have been designed which give an air stream practically free from variations in static pressure at distances from the mouth of the nozzle greater than two diameters. At higher speeds, however, standing pressure waves of approximately sine-wave form are present in the jet to a distance of six diameters or more from the mouth of the nozzle.

In cooperation with the National Advisory Committee for Aeronautics, measurements have been made at Edgewood Arsenal of the pressure distribution over six airfoils ranging in camber ratio from 0.10 to 0.20 at speeds from 0.5 to 1.08 times the speed of sound. The measurements were made in a free-air stream 2 inches in diameter, using airfoils of 1 inch chord length. An analysis of these results is now in progress.

The study of the design of fins for the stabilization of aircraft bombs has been continued in cooperation with the Ordnance Department of the Army. Tests have been extended to cover a large range of aspect ratio and the results have been analyzed in such a way that it is possible to predict from the drawing of a bomb the position of the center of pressure with a precision of about 3 per cent of the bomb length. In addition it has been possible to suggest certain modifications which lead to more economical use of material in that equal or greater stability can be secured by smaller fins. The utility of these modifications has been confirmed by dropping bombs with the modified fins and comparing their behavior with bombs having fins of the original type.

Measurements of the characteristics of one type of bomb have been carried through a range of 360° and the results utilized in certain step-by-step computations of actual bomb trajectories, which differ considerably from trajectories computed on the assumption that the bomb remains always tangent to its trajectory.

In cooperation with the National Advisory Committee for Aeronautics an investigation has been made of turbulence in wind tunnels. The measurements were made in the 4½-foot tunnel and consisted of measurements of the drag of cylinders in the turbulent region behind screens of fine and coarse mesh and of measurements of variations in static pressure. The results are described in detail in a technical report of the committee.

Measurements have been completed of the distribution of pressure over the surface of a square-base prism, 8 by 8 by 24 inches, with the wind normal to the axis of the prism but at various angles to the face. The measurements were carried out in the 10-foot wind tunnel at speeds up to 70 miles per hour. The distribution of pressure over a cylinder 8 inches in diameter and 60 inches long with axis normal to the wind has been measured in the same tunnel and measurements on a cylinder 12 inches in diameter are in progress. These studies are parts of an investigation of the wind pressure on structures.

A number of tests were made at the request of the Select Committee of Inquiry into Operations of the United States Air Services.

At the request of the editors of the International Critical Tables, members of the staff have collected the data for the aerodynamics section of the tables.

An investigation of the aerodynamic characteristics of airfoils at high speeds which was carried out in cooperation with the National Advisory Committee for Aeronautics has been published during the year as Technical Report No. 207 of this committee.

Aeronautic instrument investigations.—The aeronautic instruments section of the Bureau of Standards has continued its program of cooperative research and development work on aircraft instruments with the National Advisory Committee for Aeronautics, the Navy, the Army, and other Government departments and private concerns.

A number of special flight-test instruments have been constructed for the National Advisory Committee for Aeronautics. These instruments include an electric resistance-type thermometer for measuring very low air temperatures, a small highly sensitive galvanometer, and a small gyroscope for use in a turn recorder. A camera sextant has been built for the Bureau of Aeronautics for use on the Navy rigid airships. This sextant photographs on a strip of bromide paper images of the sun and of a bubble level and the reference scales. The advantage of the instrument lies in the fact that the images of the sun and bubble need not be brought to coincidence on the central line, but their distances from this line can be measured on the finished print and the necessary corrections applied. A small portable developing tank makes it possible to obtain a finished print within five minutes' time of the exposure.

Theoretical and experimental researches in connection with the improvement of aeronautic instruments have been continued. A catalogue has been prepared for the engineering division of the Army Air Service of various types of aeronautic instrument mechanisms showing diagrammatically the various parts, giving brief descriptions of the mechanisms, and discussing their performance. The analysis of the toggle arm used in many mechanisms has been extended to air-speed indicators, as well as to altimeters. A new mechanism giving a straight scale, in contrast to the usual circular scale, has been investigated and is being used in two tachometers under construction for the Bureau of Aeronautics. The experimental investigation of the static and running friction of small instrument bearings has been continued with definite progress. A report has been prepared on the investigation of pressure elements, which was undertaken for the engineering division of the Army Air Service. An investigation of the errors of mercurial barometers is also in progress for the purpose of studying the unexplained inaccuracies in the readings of these instruments and the means for their elimination. An investigation of hysteresis in bars of various metals and its relation to the damping of the vibrations of tuning forks is in progress. The theory of the deflection of bimetallic bars has been generalized to include bimetallic plates.

Programs and material for discussion have been prepared for two conferences of representatives of the National Advisory Committee for Aeronautics, the Bureau of Standards, the Army Air Service, the Naval Bureau of Aeronautics, the Weather Bureau, and the National Aeronautic Association, conducted under the auspices of the National Advisory Committee for Aeronautics. The first of these conferences approved and secured the official adoption for use in the United States of a new altimeter calibration standard based on the Toussaint standard atmosphere. The new standard, which constitutes a distinct improvement in the calibration of altimeters, represents quite accurately yearly average atmospheric conditions both in the United States and in Europe, in contrast to the old standard which assumed an isothermal air column whose temperature was +10° C. The second conference, made up of representatives of the same organizations as the first, adopted resolutions regarding the determination of altitudes which have been forwarded as United States recommendations to the Federation Aeronautique Internationale with a view to improving the accuracy of the methods now in use for establishing altitudes attained in the attempt to establish new altitude records.

During the past year two publications, National Advisory Committee Technical Reports No. 198, "Astronomical Methods in Aerial Navigation," and No. 206, "Nonmetallic Diaphragms for Instruments," were published.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Wind tunnels and instrumental equipment.—The efforts of the wind-tunnel staff during the year have been concentrated on the installation and test of the propeller dynamometer and auxiliary apparatus in the 7½-foot wind tunnel. The installation of the dynamometer was completed early in the year, and after some calibration it was put into use for regular propeller testing. Propellers have been run up to a tip speed of over 400 feet per second, with continuous measurement of thrust and torque.

The dynamometer was planned for the particular purpose of testing propellers and models in the presence each of the other and measuring the interferences between them, and is so designed as to permit the making of such interference tests at any angle of attack. The model under test is supported on wires, and the three forces and three moments acting are all read simultaneously by six identical automatic balances from which the wires depend. Readings for all forces and moments can be obtained in about five seconds after the model has been adjusted to the correct attitude. The first tests on interference are being made on a ¼-scale model of a DH-4B, the wings being clipped to permit it to enter the tunnel.

Propeller tests.—As already noted, several model propellers representing designs in actual use by the Army have been tested for thrust and torque over the operating range of slip ratios. Tests were run at a number of different rotational speeds for the same slip ratio, and indicated a scale effect considerably larger than had been anticipated, especially for models of wooden propellers designed for high-powered engines and having very thick sections near the boss.

Model tests.—The practice of testing complete models for the Army Air Service has been continued. As in the previous years, special attention has been given to control and stability characteristics.

Miscellaneous.—The small wind tunnel (4-foot diameter) has been employed much of the time for instruction and for researches carried out independently by students. Among the pieces of work undertaken there have been included an analysis of the elements affecting the longitudinal balance of an airplane and a study of the autorotation characteristics of windmills or helicopter propellers inclined at various angles to the wind stream.

McCOOK FIELD

General.—The routine work at McCook Field during the past year has included complete tests on 13 airplane models, with a rather elaborate investigation of the effect on fuselage, chassis, tail surfaces, etc., determined by successive removal of these parts from the model. The usual number of calibrations were made on aircraft instruments as requested from time to time by the flight or instrument branch. Routine airfoil tests numbered 15; miscellaneous tests, 30; and airfoil tests for wall interference studies, 320.

Wall interference investigation.—A series of seven geometrically similar airfoils was prepared, of differing sizes and having 0.15 cylindrical camber, chosen for the purpose of exaggerating the effects under examination. These surfaces were tested at slow speeds on the N. P. L. balance, and at speeds up to 250 miles per hour on the wire balance. In addition, a series of five C-27 airfoils of differing sizes was tested on the N. P. L. balance.

In connection with this series of tests pressure traverses were made, the laborious nature of these having been lately reduced by the use of improved methods and in particular the development of the "integrating impact tube." Pressure drops due to various models in the tunnel were measured and interpreted to a precision of three-tenths of 1 per cent on the velocity head.

Some rough outdoor tests were conducted to investigate new methods of checking wall interference, using a rotary wind-driven propeller as the most convenient object for test.

Alteration of the air flow of the 5-foot wind tunnel.—The character of air flow has been altered by the installation of an improved form of straightener, and by the elimination of the honeycomb. This alteration was intended for the original layout of the tunnel in 1922, but it was not convenient at that time to install it. A new arrangement of the static plate orifices has been installed, and the whole recalibrated. The previous flow had a turbulence corresponding to about 12 per cent of the velocity head; the new flow has a turbulence corresponding to about 2½ per cent of the velocity head. The new straightener by which this change has been accomplished is a development from the straightener first used in the 14-inch wind tunnel in 1918, and has been the result of various empirical studies since that time, and in particular some model studies in the 14-inch wind tunnel in 1925.

Officers' school.—The usual period required by the McCook Field Officers' School was devoted to instructing 13 officers in wind-tunnel procedure.

Twenty-foot wind tunnel project.—In the summer of 1924 a 20-foot wind-tunnel project for the new McCook Field was brought up, in continuation of earlier studies on large wind-tunnel design commenced by the Air Service in 1917. With the object of corroborating published data on various wind-tunnel structures, four scale models were built and tests started in February, 1924.

Parachute fabrics.—Resistance and air leakage of various parachute fabrics were examined in the wind tunnel, the general conclusions being that the closeness of the weaves examined did not noticeably change resistance.

Effect of bullet holes in wing fabric.—A full-sized portion of an MB-3A wing was put in the wind tunnel for high-speed test of the tearing effect when bullet holes existed in the fabric.

Rotating cylinder.—Stream-line flow around a rotating cylinder was determined in December, 1924, by taking photographs of a simple apparatus using the silk-streamer method. Rough observations were made on the lift and drag of the rotating cylinder.

A method was perfected along lines originated by the General Electric Co. for securing pictures of air flow over a body. The method involves painting the body with a suitable paint, subjecting same to the air flow, and photographing the result after the flow lines have formed.

Test of Carmier gun sight.—The gun sight was mounted in the wind tunnel in the manner actually used on the aircraft gun, and its behavior under various accelerations was noted.

Humidifying apparatus in the 14-inch wind tunnel.—For purposes of visualizing air flow in the high-speed wind tunnel, water-humidifying nozzles were installed in the hangar. Previously it has been customary to await suitable weather humidity conditions when it is desired to make observations of air flow.

Center section type of radiator.—Half-size sections of air foils were tested for comparative resistance with and without radiator.

REPORT OF COMMITTEE ON POWER PLANTS FOR AIRCRAFT

ORGANIZATION

The committee on power plants for aircraft is at present composed of the following members:

Dr. S. W. Stratton, Massachusetts Institute of Technology, chairman.
George W. Lewis, National Advisory Committee for Aeronautics, vice chairman.
Henry M. Crane, Society of Automotive Engineers.
Prof. Harvey N. Davis, Harvard University.
Dr. H. C. Dickinson, Bureau of Standards.
Leigh M. Griffith, Langley Memorial Aeronautical Laboratory.
Edward T. Jones, engineering division, Army Air Service, McCook Field.
Commander E. E. Wilson, United States Navy.

FUNCTIONS

The functions of the committee on power plants for aircraft are as follows:

1. To determine which problems in the field of aeronautic power-plant research are the most important for investigation by governmental and private agencies.
2. To coordinate by counsel and suggestion the research work involved in the investigation of such problems.
3. To act as a medium for the interchange of information regarding aeronautic power-plant research, in progress or proposed.
4. To direct and conduct research on aeronautic power-plant problems in such laboratories as may be placed either in whole or in part under its direction.
5. To meet from time to time on call of the chairman and report its actions and recommendations to the executive committee.

By reason of the representation of the Army, the Navy, the Bureau of Standards, and the industry upon this subcommittee, it is possible to maintain close contact with the research work being carried on in this country and to exert an influence toward the expenditure of energy on those problems whose solution appears to be of the greatest importance, as well as to avoid waste of effort due to unnecessary duplication of research.

The committee on power plants for aircraft has direct control of the power-plant research conducted at Langley Field and also of special investigations authorized by the committee and conducted at the Bureau of Standards. Other power-plant investigations undertaken by the Army Air Service or the Bureau of Aeronautics are reported upon at the meetings of the committee on power plants for aircraft.

SUBCOMMITTEE ON ACCIDENTS

In order to determine, if possible, the exact causes of aircraft accidents, the greater number of which are due to failure of some part of the power-plant installation, a subcommittee on accidents has been organized as a subcommittee of the committee on power plants for aircraft. The functions of this subcommittee are to assemble and analyze data on accidents in the Army, Navy, and Postal Air Services with a view to determining the types of matériel failures which most commonly occur in aircraft. The organization of the subcommittee on accidents is as follows:

G. W. Lewis, National Advisory Committee for Aeronautics, chairman;
Lieut. B. R. Dallas, United States Army;
Lieut. W. H. Dillon, United States Navy;
C. F. Egge, Air Mail Service.

LANGLEY MEMORIAL AERONAUTICAL LABORATORY

FUEL INJECTION ENGINE—*Engine performance.*—The study of the application of fuel injection to the two-cycle engine with spark ignition has been continued and brought to a conclusion. The induction system of the Liberty engine cylinder was further modified, which gave improved results. The study did not include design development necessary to permit satisfactory operation at low speeds and loads. It was found that 53 brake horsepower could be consistently developed with the modified Liberty cylinder at 1,300 revolutions per minute (116 lbs./sq. in. B. M. E. P.), using a scavenging air pressure of 5½ lbs./sq. in. Only 28 brake horsepower is obtained with the standard Liberty engine at the same speed. A report covering this work has been prepared for publication.

The application of fuel injection to four-cycle aeronautic engines operating with Diesel engine fuel oil and using the heat of compression for igniting the fuel has been further studied. A special steel cylinder mounted on the single cylinder Liberty engine base and arranged for the adaptation of separate cylinder heads has been used to study combustion-chamber forms. A precombustion or bulb-type cylinder head has been tested at speeds up to 1,800 revolutions per minute, using an eccentric-operated pump and an automatic diaphragm-type injection valve. Brake mean effective pressures up to 88 lbs./sq. in. and fuel economies comparable to those of present-day aircraft engines have been obtained with an injection advance angle of approximately 27° before top dead center. The low compression pressure of 280 lbs./sq. in., high explosion pressures, and certain features of construction have, however, limited the possibilities of obtaining a higher satisfactory power performance with this cylinder head.

A new cylinder head of the same general type has been designed and is being constructed which will permit compression pressures up to 500 lbs./sq. in. and which provides for various precombustion chamber volumes and shapes and degrees of turbulence.

A second head of slightly concave cross section and arranged for injection of fuel directly into the cylinder is being tested. A cam-operated fuel pump and a spring-loaded type of injection valve are being used in this work. A limited number of tests have been made to determine the effect of variation of the injection rate on the power output and fuel economy. In connection with these tests a simple device for determining maximum explosion pressures has been developed, by the aid of which it has been possible to maintain definite cylinder pressures for comparative purposes. Although the results with these two heads are not exactly comparable, they indicate at this time that the precombustion chamber type of cylinder head is the more promising of the two for aeronautic application.

The Universal test engine has been fitted with an eccentric-operated pump and automatic diaphragm-type valves. An investigation of the influence of compression pressure on the performance of this engine operating as a compression ignition engine has been started. This engine is peculiarly adaptable for such work, since the compression pressure can be changed readily while the engine is in operation by raising or lowering the cylinder head. Preliminary tests at 1,400 revolutions per minute have given fuel consumptions of 0.50 pound per brake horsepower-hour for loads up to 60 lbs./sq. in. brake mean effective pressure. Owing to the form of the combustion chamber combined with lack of effective turbulence, satisfactory performance at higher power was not obtained.

Fuel injection pumps and valves.—The performance of an eccentric-operated injection pump which controls injection by means of a relief valve has been determined with special bench testing equipment, consisting essentially of a motor-driven jackshaft with a flywheel, and provided for attaching fuel pumps, and a deflector and clutch mechanism which permit the passage at will of one or more sprays to a target held on and rotated with the flywheel. By means of this apparatus the effects of speed, injection-valve opening pressure, primary fuel pressure, injection-valve tube length, and closure of the relief valve at various points in the pump cycle on the lag of the spray behind the pump cycle have been determined. The duration of injection, the maximum injection pressures developed, and the fuel weight discharged per cycle for various pump settings were also determined. This work has aided materially the study of the application of injection systems to engine service and the analysis of engine performance.

Two types of automatic diaphragm-type injection valves giving highly atomized fuel sprays have been developed. The first type discharges the fuel at the periphery of the diaphragms and the second through a steel nozzle supported in the center of the diaphragm. Conical sprays, having spray cone angles up to 130°, and obtained by means of either mechanical guides or rotation of the jet, have been studied.

Characteristics of fuel sprays.—Further development of the apparatus for taking a series of pictures at high speed of the growth of a single fuel spray has resulted in the determination of the penetration characteristics of the sprays of several types of injection valves. A description of the apparatus used for this work may be found in the previous annual reports of the committee. A series of tests have been made which give the penetration and development with time of sprays produced by a positively operated injection valve having a 0.015-inch round orifice. Diesel-engine fuel oil was discharged through this orifice at pressures up to 8,000 lbs./sq. in. into a chamber with glass windows containing nitrogen at pressures up to 300 lbs./sq. in. and a series of photographs taken of the spray during discharge. The results provide means for determining the relationships existing between the chamber and fuel pressures, and a report covering this work, entitled "Spray Penetration with a Simple Fuel Injection Nozzle," has been prepared for publication.

Investigations with this apparatus are now under way on the spray characteristics of several automatic injection valves, using chamber pressures up to 600 lbs./sq. in. and controlling the weight of the fuel discharged. The results to date show that under the same conditions the spray from a simple round orifice has greater penetration, smaller cone angles, and lesser atomization than other types of sprays. While mechanically guided wide angle sprays may have initial velocities as high as those having narrow angles, it is found that they atomize more quickly and thoroughly and have less penetration. The effect of chamber pressure on centrifugal sprays is to decrease materially their spray cone angles and tend to maintain their axial penetration.

Fuel characteristics.—The work on the vapor pressure-temperature characteristics of several fuels used in internal combustion engines has been limited to an investigation of the behavior of various mixtures of gasoline and benzol and a study of the reactions and phenomena noted in the experimental work.

A report has been prepared for publication covering the investigation of the effects of fuel pressure, back-air pressure, and temperature on the coefficients of discharge of various fuels discharged through round orifices suitable for use in fuel-injection valves.

SUPERCHARGING—*Roots type.*—Comparative climb performance tests with and without supercharging of a DT-2 sea plane carrying equivalent military loads up to 2,000 pounds have been completed, and the results have shown that a material improvement in the performance of this type airplane can be obtained by supercharging even when heavily loaded and operating to moderate altitudes. It was found that when maintaining practically sea-level pressure at the carburetor at all times when supercharging the absolute ceiling was increased 90 per cent when operating without military load and 50 per cent when operating with load. The service ceiling was increased about 80 per cent for all loads, while the average rate of climb to the service ceiling was the same. The climb performance when supercharging was inferior at low altitudes, owing to the use of large propellers.

The first successful supercharging of an air-cooled engine at high altitude has been accomplished at this laboratory, using the Roots type supercharger. Further tests with the Lawrance (Wright) J-1 engine with Roots supercharger in a TS land plane have been completed. When using the same propeller and maintaining full supercharging to 16,000 feet, the original service ceiling of 16,100 feet was increased 65 per cent, the absolute ceiling was increased 56 per cent, the time to 16,100 feet was reduced 59 per cent, and the average rate of climb to the new service ceiling was 43 per cent greater than to the original ceiling without supercharging. Additional information of the effect of supercharging on the cylinder head temperatures of each of the nine cylinders has been obtained, giving maximum recorded temperatures for the various cylinders ranging between 500° F. and 560° F. Close examination of the engine revealed no undue wear or other ill effects as a result of supercharging.

In addition to the above investigation with the model J-1 engine, a further study has been made, using a Roots type supercharger and a Wright model J-4 air-cooled engine in a UO-1 land plane, with a view to learning the effects of supercharging on an engine having a somewhat different cylinder construction. With full supercharging maintained to 18,000 feet, a considerable increase in airplane performance was obtained with apparently no detriment to the engine and without encountering excessive cylinder head temperatures. When operating with the above amount of supercharging and using the same propeller, the original service ceiling of 18,300 feet was increased 72 per cent, the original absolute ceiling of 20,000 feet was increased 66 per cent, the time to 18,300 feet was reduced 54 per cent, and the average rate of climb to the service ceiling was 27 per cent greater than to the original service ceiling without supercharging. Cylinder head temperatures measured at corresponding points on each of the nine cylinders showed a variation among the cylinders of about 150° F. The maximum head temperature under supercharged conditions was 530° F. against a maximum of 470° F. for the unsupercharged condition. Investigation with the J-4 engine is being continued using an increased amount of supercharging.

Further study of the Roots type supercharger has been made in the laboratory to obtain additional information on its performance characteristics.

A DH-4 airplane has been reconditioned and equipped especially for continuing the investigation of the flight characteristics of the Roots type supercharger.

Additional Roots superchargers are being constructed in which are incorporated changes in design found desirable from experience with the present machine. As the new machines will be capable of being operated at speeds much higher than the present machine, it will be possible to study the effect of the higher speeds on the performance characteristics, and thus determine the advisability of increasing the speed of operation and reducing the size and weight of the unit.

Problems incidental to supercharging.—An investigation to determine the effect of high carburetor air temperatures, such as encountered when supercharging, on the power output of water-cooled engines has been completed, and information has been obtained for a Wright model E-4 engine and a Liberty-12 engine with carburetor air temperatures as high as 180° F. This study has shown that, for the higher air temperatures, the relation between engine power and air temperature remains substantially the same as found by other investigators for the lower ranges of temperature.

In connection with the study of methods for measuring the power output of supercharged engines operating at altitude, a Bendemann hub dynamometer has been tested on the stand to ascertain its suitability for the purpose.

Supercharged engine versus other types.—A study of the relative performance of the normal compression engine, the high compression engine, and the supercharged normal compression engine has been continued both in the laboratory and in flight. Tests have been continued with the single cylinder Universal test engine to establish the performance attainable with the high-compression engine without encountering serious detonation when using domestic aviation gasoline. Tests have been conducted with normal ignition advance and the engine throttle by means of the usual butterfly valve, with retarded ignition and engine not throttled and with volumetric efficiency of the engine reduced by varying the timing of the inlet valve. Compression ratios from 4 : 1 to 7.5 : 1 and engine speeds from 1,200 to 1,800 revolutions per minute were investigated, and the factors influencing detonation, such as volumetric efficiency, ignition timing, air-fuel ratio, and piston velocity, were studied. The results have shown that the maximum power output of the high compression engine operating on domestic aviation gasoline at sea level is obtained by maintaining full throttle and retarding the ignition timing sufficiently to suppress detonation, although the fuel consumption with this method is high. In order to make the test results comparable during this investigation, it was necessary to restrict the detonation to a definite amount. Consequently, considerable attention was given to the study of laboratory methods of detecting and measuring detonation. Limitations of methods previously used were established and several new methods tried. A simple apparatus, consisting of a sensitive balanced pressure ball valve, was finally adopted as being best suited to the conditions of these tests.

The results of the above tests will be used in connection with the program of flight tests which is being conducted to determine the relative performance of a service type seaplane of the load-carrying type, equipped with a normal compression engine, a high compression engine, and a supercharged normal compression engine, all engines having the same displacement and being used both with direct and geared propeller drives. Flight tests with a normal compression Wright T-2 engine in a DT-4 seaplane are now in progress.

POWER PLANT LABORATORY EQUIPMENT.—A small gasometer has been installed and used in conjunction with a special surge chamber for measuring the air consumption of single-cylinder test engines. A second gasometer, of larger capacity, is being installed.

Several detail changes have been made in the Universal test engine. This unit has proved very satisfactory for research purposes.

BUREAU OF STANDARDS

Testing of aviation engines under approximate altitude conditions.—Engine tests under approximate altitude conditions have been made by reducing the pressure at the entrance to the carburetor and at the exhaust port exactly as in an altitude laboratory test but allowing the air surrounding the engine to remain at sea-level pressure. Similar tests were made under "true" altitude conditions—that is to say, with the air surrounding the engine reduced to a pressure corresponding to the altitude. It was concluded that with certain precautions satisfactory results would ordinarily be expected with the approximate type of test.

Supercharging of aircraft engines.—Tests of a Curtiss D-12 engine under supercharging conditions have been made for pressures and temperatures up to those corresponding to an altitude of 15,000 feet. Preparations for a more extensive series of tests with another engine are in progress. This work is so planned as to cover the range of pressures to be expected with the exhaust or the mechanically driven superchargers and should furnish a basis for estimating the performance of an engine equipped with any type of supercharger once the power consumed by that particular device in maintaining a given amount of supercharging is known.

Ignition systems.—A rather complete series of comparative tests of ignition systems has been completed, on the basis of which a report on the "Electrical Characteristics of Iginition Systems" has been prepared.

Phenomena of combustion.—This investigation of factors of fundamental importance as regards the rate of explosive gaseous reactions has been in progress for several years. A soap bubble serves as a constant pressure bomb, the record of the explosive reaction being secured automatically by photographic means. During the past year there has been completed and installed a large container within which the soap bubble can be used as a constant pressure bomb at pressures above or below atmospheric. The apparatus has proved very satisfactory and several groups of measurements have been made.

Fuels for high-compression engines.—A report summarizing the work at the bureau on this subject during the past few years has been submitted to the National Advisory Committee for Aeronautics for publication. The report is primarily a general discussion of the properties essential to a satisfactory fuel for high-compression engines, but certain fuels, benzol and alcohol in particular, are discussed in some detail.

Oxidation test for routine testing of mineral oils.—The oxidation test, the development of which was discussed in the report of last year, has been employed to a considerable extent throughout the year at the bureau and at several other laboratories. It appears to have proved as satisfactory as was anticipated. In this test the oil is subjected for two and one-half hours to a temperature of 200° C. in an atmosphere of oxygen.

Investigation of bearing friction.—Several oils have been compared in the journal friction machine and very consistent results have been obtained. Considerable new apparatus has been constructed, including a simple friction machine for investigating the effect of viscosity upon wear when an abrasive is in the oil. Preliminary tests indicate that this machine will prove to be unusually valuable.

Investigation of piston friction.—This project had as its aim the finding of the relative magnitude of certain factors affecting piston friction in order that the friction of engines, particularly those of the aviation type, might be more accurately estimated. The experimental work has consisted of measurements of the friction of a four-cylinder engine equipped with several groups of pistons, each group differing from the standard pistons in but one respect. The experimental work on this investigation has been completed and a report is in preparation.

Hot wire anemometer.—A technologic paper has been prepared and published describing the hot wire anemometer which was constructed to measure the average flow of air through radiators mounted in different positions on an airplane.

NEW ENGINE TYPES

Both the Bureau of Aeronautics of the Navy Department and the engineering division of the Army Air Service have continued their efforts toward an increase in the dependability of aircraft engines and their accessories and in bringing about a greater life between overhauls. The two organizations have cooperated closely in developments. The Air Service has continued work on the cam engine and barrel type or Almen engine. The Bureau of Aeronautics has been conducting tests on its experimental heavy-oil engine purchased from the Eastern Engineering Co. (Ltd.), Montreal, Canada. This engine has not developed the power anticipated, but it has demonstrated conclusively that heavy oil can be properly burned in high-speed engines of the two-stroke autoignition, solid-injection type. Development is continuing on the project and promising results have been obtained.

A striking piece of work on the part of the Air Service is the new air-cooled Liberty. This engine has demonstrated on test that the air-cooled in-line engine will be one of the importan developments of the future.

Of the service types the Wright Model "J" has advanced to the J-4-A model. The Navy has 140 of these on order, of which a large number have been delivered. Contracts will soon be let for an additional order of the model J-5 which involves an improved cylinder construction. Forty-five J-4 engines have been sold to commercial activities in the United States and to foreign countries in the Western Hemisphere. A life between overhauls of about 200 hours is being obtained and very dependable performance has resulted.

The Wright Model T-3A, a 600-horsepower water-cooled engine for the combined scouting-torpedo-bombing airplanes, is now in general service and has given excellent results. This engine has now advanced to the T-3A type, incorporating minor improvements and changes designed to bring about a life between overhauls of 300 hours.

The Wright Model P-2, the 400-horsepower static-radial, air-cooled engine, which incorporates the fan-type supercharger for rotary induction purposes, has passed its acceptance tests with very excellent performance. Twelve of these engines have been ordered for flight testing purposes and for further development looking toward the service application of this engine at a future date.

The Wright Aeronautical Corporation is developing a new engine of 1,200 cubic inches capacity, scaled down from the P-2 model. This will produce a line of three air-cooled engines in 800, 1,200, and 1,600 cubic inches, designed to meet the Navy's needs in all types of aircraft. The model "J" will be used as a training engine, the new R-1200 in the observation and fighter class, and the large P-2 for single and twin-engined bomber installation.

Both the Army and the Navy have continued the development of the Packard 1A-1500 and 1A-2500 engines. The inverted 1500 is being used in the Loening amphibian, the vertical 1500 in fighters, and the geared 1500 in the large patrol airplane. This latter engine was the power plant for the PN-9's used on the San Francisco to Hawaii project. The first PN-9 holds the world's endurance record for sea planes at 28 hours and 35 minutes, and the same airplane on the Honolulu flight had perfect engine performance until the gasoline was exhausted. The Packard 1A-2500, 800-horsepower water-cooled engine geared two to one, was installed in the Boeing patrol airplane for the same project. The engine performance of this airplane has likewise been satisfactory.

The Curtiss D-12 engine has continued to give excellent results in pursuit-type airplanes and more of these engines are being purchased. The Curtiss radial R-1454, a 400-horsepower air-cooled engine developed by the Air Service, has been delivered at McCook Field and is now undergoing its tests. This engine incorporates the rotary induction and improved cylinder design, from which good performance is anticipated.

The new Curtiss V-1400, a 12-cylinder V-type water-cooled engine, has lately passed its tests and was flown for the first time in the Pulitzer races. This engine has very striking characteristics of high power, light weight, rugged construction, and accessibility.

In the field of accessories the aeromarine inertia type hand starter has become standard in the Navy and has definitely proved its effectiveness. The scintilla magnetos adopted for general Navy use have likewise measured up to all expectations. There has been continued improvement in all accessory equipment and continued improvement in general dependability.

The rise of the air-cooled engine with improved reduction in power-plant weights, due to the elimination of the cooling system, has forced the water-cooled engine to new endeavors. Increased power through higher crankshaft speeds with reduction gearing has brought about a balance on the basis of specific power-plant weights between the two engines. This will undoubtedly force the air-cooled engine into the higher speeds and reduction gearing. Since results indicate that a large percentage of power-plant failures are due to faults in gasoline, oil, and water lines, the air-cooled engine still has important advantages. This fact accounts for the energy which is now being put into development of the three air-cooled engines for the Navy.

The past year has been marked by the entrance into the aircraft engine field of the Pratt & Whitney Aircraft Co., of Hartford, Conn. The formation of this company brings to the industry the wide experience of the officers of the new company and the well-known manufacturing facilities of Pratt & Whitney.

In general, the Bureau of Aeronautics and the Air Service are cooperating very closely in engine development, and this development is taking the form of improved performance, improved dependability, and increased life between overhauls. The development problem has followed a rational line, and has therefore been a healthy one.

REPORT OF COMMITTEE ON MATERIALS FOR AIRCRAFT

ORGANIZATION

The present organization of the committee on materials for aircraft is as follows:

Dr. George K. Burgess, Bureau of Standards, chairman.
Dr. H. L. Whittemore, Bureau of Standards, vice chairman.
S. K. Colby, American Magnesium Corporation.
Henry A. Gardner, Institute of Paint and Varnish Research.
Dr. H. W. Gillett, Bureau of Standards.
Prof. George B. Haven, Massachusetts Institute of Technology.
Zay Jeffries, Aluminum Company of America.
J. B. Johnson, engineering division, Army Air Service, McCook Field.
George W. Lewis, National Advisory Committee for Aeronautics (ex officio member).
Commander H. C. Richardson, United States Navy.
G. W. Trayer, Forest Products Laboratory, Forest Service.
Starr Truscott, Bureau of Aeronautics, Navy Department.
Prof. Edward P. Warner, Massachusetts Institute of Technology.

FUNCTIONS

Following is a statement of the functions of the committee on materials for aircraft:

1. To aid in determining the problems relating to materials for aircraft to be solved experimentally by governmental and private agencies.

2. To endeavor to coordinate, by counsel and suggestion, the research and experimental work involved in the investigation of such problems.

3. To act as a medium for the interchange of information regarding investigations of materials for aircraft, in progress or proposed.

4. To direct and conduct research and experiment on materials for aircraft in such laboratory or laboratories, either in whole or in part, as may be placed under its direction.

5. To meet from time to time on call of the chairman and report its actions and recommendations to the executive committee.

The committee on materials for aircraft, through its personnel acting as a medium for the interchange of information regarding investigations on materials for aircraft, is enabled to keep in close touch with research in this field of aircraft development. Much of the research, especially in the development of light alloys, must necessarily be conducted by the manufacturers interested in the particular problems, and both the Aluminum Co. of America and the American Magnesium Corporation are represented on the committee. In order to cover effectively the large and varied field of research on materials for aircraft, three subcommittees have been formed, as follows:

Subcommittee on metals:
- Dr. H. W. Gillett, Bureau of Standards, chairman.
- Zay Jeffries, Aluminum Co. of America.
- J. B. Johnson, engineering division, Army Air Service, McCook Field.
- George W. Lewis, National Advisory Committee for Aeronautics (ex officio member).
- Starr Truscott, Bureau of Aeronautics, Navy Department.
- Dr. H. L. Whittemore, Bureau of Standards.

Subcommittee on woods and glues:
- G. W. Trayer, Forest Products Laboratory, Forest Service, chairman.
- H. S. Betts, Forest Service.
- George W. Lewis (ex officio member).
- Dr. H. L. Whittemore, Bureau of Standards.

Subcommittee on coverings, dopes, and protective coatings:
- Henry A. Gardner, Institute of Paint and Varnish Research, chairman
- Dr. W. Blum, Bureau of Standards.
- Warren E. Emley, Bureau of Standards.
- Prof. George B. Haven, Massachusetts Institute of Technology.
- Isadore M. Jacobsohn, Bureau of Standards.
- George W. Lewis (ex officio member).
- P. H. Walker, Bureau of Standards.
- E. R. Weaver, Bureau of Standards.

During the past year, Mr. G. W. Trayer, of the Forest Products Laboratory, has replaced Mr. Carlile P. Winslow on the committee on materials for aircraft. Dr. H. W. Gillett, of the Bureau of Standards, has been appointed a member of the committee and chairman of the subcommittee on metals, succeeding Dr. George K. Burgess in the latter capacity. Mr. Starr Truscott, of the Bureau of Aeronautics of the Navy Department, has also been appointed a member of the committee on materials for aircraft and of the subcommittee on metals, and Mr. Warren E. Emley, of the Bureau of Standards, has been appointed a member of the subcommittee on coverings, dopes, and protective coatings.

Most of the research in connection with the development of materials for aircraft is financed directly by the Bureau of Aeronautics of the Navy Department, the engineering division of the Army Air Service, and the National Advisory Committee for Aeronautics.

The Bureau of Aeronautics and the engineering division of the Air Service, in connection with the operation of tests in their own laboratories, apportion and finance research problems on materials for aircraft to the Bureau of Standards, the Forest Products Laboratory, and the Industrial Research Laboratories.

MEETINGS OF THE COMMITTEE

Several very important meetings of the committee were held during the year. One was held at the Naval Aircraft Factory, Philadelphia, at which the subject of the corrosion of duralumin and its embrittlement was very thoroughly discussed by members of the committee and by representatives of the manufacturers of this, the most widely used light alloy. After the meeting the work in progress at the factory was inspected. A great deal of interest was shown in the PN-9 seaplanes, which were later used in the attempted flight from San Francisco to Hawaii.

SUBSTITUTE FOR SILK PARACHUTE FABRIC

The problem of finding a substitute for the silk which is now used in parachute construction is a part of the general program of this committee. An investigation has been under way for the fabrication of a cloth in this country which will prove acceptable for parachute construction. Acceptable silk fabrics have been produced from the raw materials obtained from China and Japan and fabricated in this country. Since it has never proved practical to cultivate silk in the United States, the problem resolves itself into finding some other fiber which can be substituted for the raw silk fiber.

In order to design a cloth as light as the requirements demand for parachute cloth, fine yarns must be used which can be manufactured from cottons only of long staple. The Pima cotton, which is grown in Arizona, will provide this yarn, and the investigation so far has been made with Sakellaridis cotton, which is practically the same.

Using fine yarns, both singles and doubles, a very careful study has been made of the physical properties in comparison with silk yarns of similar size. The characteristics which are most important are strength, stretch, and resiliency. Advantage was taken of previous work done in the textile field showing the reaction which cotton undergoes during mercerization and treatments with dopes and softeners. Seven treatments were tried and the results of the study permitted the selection of one type of treatment for further study, namely, the coating of the previously mercerized cotton with cellulose acetate dopes containing dissolved resins and softeners. Three distinct types of cellulose acetate dopes were used. The yarns used in the investigation had been mercerized commercially and it was found that this mercerization process had a very decided effect on the strength and elasticity of the yarn. A study of the mercerization was made in conjunction with tests of yarns wet treated and dry treated. In the process of mercerization there are three main operations: The premercerization treatment; the formation of alkali cellulose; and the formation of cellulose hydrate. Each of these three operations requires several minor operations, and in this investigation a study was made of the effect of the variations in the conditions under which the operations were carried out on the properties of the finished mercerized cotton. The yarns used in the investigation were 160/1 and 160/2, five different twists for the single and three each for the plied yarns being used.

The successful conclusion of this investigation will depend largely upon the result of the mercerization experiments. The work so far has been very encouraging, and it is hoped that a definite conclusion will be reached toward the end of the present fiscal year.

SUBCOMMITTEE ON METALS

Intercrystalline embrittlement of duralumin.—During the past year the subcommittee on metals recommended a program of research for the study of intercrystalline embrittlement of duralumin. This program was approved by the National Advisory Committee for Aeronautics and recommended to the Army Air Service, the Bureau of Aeronautics, and the Post Office Department for consideration, and has been accepted by the Air Service and the Bureau of Aeronautics.

The outline of this program is as follows:

(*a*) The study of acceleration of this type of corrosion for testing purposes.

(*b*) The effect of permanent deformation on material hardened by spontaneous aging.

(c) The effect of deformation on fully hardened material, hardened by accelerated aging at a higher temperature.

(d) The effect of protective coatings.

(e) The effect of gas during the casting.

(f) The effect of heating and quenching mediums.

(g) The effect of the composition of the duralumin tested.

Material with a carefully recorded history of its preparation was received from the Baush Machine Tool Co., and since that material and similar material from the Aluminum Co. of America were to be studied together the investigation did not start until the material from the latter company was received, late in August. Specimens for testing were then made from both lots.

Intercrystalline attack and embrittlement in material received from both companies has been produced experimentally, both in aged material and in that cold-rolled after aging. A study of the rate of attack in calcium chloride solutions of varying strength with specimens both submerged and alternately submerged and dried is in progress.

Material which had been greatly deformed by rolling after aging and slightly deformed by stretching is under test. Preliminary results indicate that stretching prior to test hastens the intercrystalline corrosive attack. Specimens are being sent to the Naval Aircraft Factory and to the Industrial Research Laboratories for coating with various protective coatings. Chemical and electrochemical treatments suggested by the Army as additions to the program will be included in the tests.

The Bureau of Standards has continued to examine specimens found in service. These samples all confirm the conclusion that material cold-worked after aging and subjected to corrosion is especially susceptible to embrittlement, although if the conditions are severe material which has not been worked after aging is also attacked. Material which had been attacked in service by calcium chloride, cleaned, and revarnished, was recently examined to see whether the intercrystalline attack had progressed. In making the comparison, the assumption had to be made that before the material was cleaned corrosion had progressed to the same extent as on the specimens which were tested at that time. On this assumption, no proof was found that the attack had progressed further since the previous examination. These results indicate that a coating which is actually impervious to such agents as water vapor and "salt air" prevents the corrosion. The material was in "notch-brittle" condition after cleaning and was still in that condition, although apparently no worse.

The information now in the possession of the committee does not justify a pessimistic outlook in respect to the use of duralumin as a structural material for aircraft, unless in very thin sheets. It is believed that research on the embrittlement problem will ultimately show how to prepare, protect, and use this material to insure reliability in service. It is also believed that the program for the investigation now in progress, which has been outlined above, is entirely satisfactory.

Structures for airships.—The previous tests of girders for the *Shenandoah* showed that the strength of these girders was determined by the elastic properties of the channels and the type of restraint offered by the lattices. The principal elastic constants of the channels are their two flexural stiffnesses (moments of inertia × Young's modulus) and their torsional stiffness (torsion constant × shear modulus).

The object of this investigation is to determine by tests the relative importance of these three constants in determining the strength of the girders. For this purpose it was necessary to study accurately and in detail the deformations of the channels under compressive loads, first in the girders alone and then with outside constraints applied which prevented particular types of deformation.

The technique of measurement which has been worked out has been thoroughly tested. Consistent reproducible results were obtained on the measurement of deflection and twist of the channels of a special girder. Since the lateral deflections were always accompanied by twist a series of readings was taken restraining in succession the twist of one, two, and three channels but leaving them free to deflect laterally. The girder was loaded under these conditions successively to 5,100 (no restraint), 6,740 (one channel restrained), 6,990 (two channels restrained), and 7,500 (three channels restrained) pounds. The final failure was by twist of two of the channels between restraints and by spreading of the third with buckling of the flanges.

The measurements so far made are consistent with the assumption that with the present construction the coefficient of torsional stiffness of the channels is the controlling factor in determining the load these girders will carry. The measurements will be repeated on girders of regular design to see if these confirm the conclusions.

High-speed fatigue testing.—The investigation of the available methods for high-speed fatigue testing has been continued. Two alternative methods of loading the specimen have been used, each producing the stresses by resonant flexural vibrations. In one, the drive is electrical. A method similar to this has been used by Jenkin in England, who reports successful results. In the other the drive is by means of compressed air. This latter, so far as the investigations show, gives promise of greater simplicity and is the cheaper to operate, especially if a large number of specimens are to be run simultaneously. Apparatus of this type has been built and run. The possibility of longitudinal vibrations has not as yet been investigated experimentally.

The data which have been obtained are, however, insufficient to determine whether or not this type of drive will function satisfactorily over long periods of time.

SUBCOMMITTEE ON WOODS AND GLUES

The Forest Products Laboratory of the Department of Agriculture conducts practically all the investigations on the application of woods and glues to aircraft construction. The investigations that have been conducted and reported on were undertaken at the request of the Bureau of Aeronautics of the Navy Department or the engineering division of the Army Air Service. Some of the more important investigations now in progress are outlined below.

Attachment of metal parts and fittings to wooden members.—A study of the effect of the attachment of metal parts and fittings to wooden members was undertaken chiefly to secure more complete information as to the size, number, and spacing of bolts or other fastening mediums. A study on spruce and ash using solid bolts of various lengths up to one-half inch diameter and hollow bolts ranging from five-eighths to 1 inch in diameter has been made. The results of the tests have been presented in the form of charts which give the most efficient size of bolt for given conditions. Although these charts were prepared for spruce and ash, they may be applied to other species by the introduction of an adjustment factor representing the relation of their strength in compression parallel to the grain, to that of spruce or ash.

Determination of acceptance test values.—In the inspection of wood for airplanes, the need has been felt for a simple and expeditious mechanical test which could be applied to each piece to determine its acceptability. To meet this need the Forest Products Laboratory toughness-testing machine was developed.

The toughness value of wood reflects the relation of tensile to compressive strength, while specific gravity gives an indication of the compressive strength as well as most of the other strength properties. The toughness test together with the specific gravity determination is consequently an excellent means of separating material low in strength from that of average or higher strength properties.

Studies have been made to form a satisfactory basis for the inspection and selection of suitable airplane material, and have been completed on white oak, yellow birch, white ash, and Sitka spruce. As a result of the studies an inspection method has been recommended and the Bureau of Aeronautics and the Army Air Service have now acquired a Forest Products Laboratory toughness-testing machine. It has been possible to inspect and select woods of high quality of five species for which minimum values have been established.

Use of plywood in wing beams.—A series of tests has been made on box beams of various dimensions and on I beams using plywood webs. The results lead to the conclusion that in the design of either plywood box or I beams a web thickness of 25 per cent greater than that calculated to give equal likelihood of failure by shear or compression will give the best results. The results of a series of tests made during the past two years will be issued in the form of a report and a further study will be made of wing beams of several different types and sizes to secure data on the strength and rigidity of beams and to determine the proper relation between the thickness of the web and the depth of flanges for different cross sections.

Detailed study of methods of fastening plywood.—A preliminary study was made on the use of screws for fastening three-ply wood of different species and sizes to spruce and ash frame members. In this investigation screw sizes, margins, and spacings were used which would develop as nearly as possible the full strength of the plywood without special consideration of the effect on the strength of the members receiving the screw point. As a result of these tests a table of screw sizes for different thicknesses of three-ply wood has been prepared for general design use. The investigation will be continued to include tests of plywood fastenings with small screws to secure data on the strength of such fastenings under different conditions. The study will also include the test of plywood with nails as fasteners.

Development of waterproof glues.—A study of waterproof glues includes a study of the resistance of glues under prolonged exposure to dampness. No adequate study has been made of the durability of glued joints under long periods of time. Experience indicates that in many places where glue joints are used any change in strength or water resistance is very slow. Tests will be carried on over a long period of time with different water-resistant glues to determine with some exactness the conditions under which glues will retain their original properties. Considerable information has been accumulated from the various investigations and a bulletin is now in preparation on the general subject of gluing of woods used for aircraft purposes.

Manufacture of casein water-resistant plywood.—An investigation has been carried on during the past year in an effort to produce a Grade A plywood with casein glues. Satisfactory results have been secured thus far on a laboratory scale, and plans are now being developed for one or more demonstrations on a factory scale. It is believed that by proper control of the glue and the gluing conditions it will be practicable to produce a satisfactory product in quantity. This investigation will be completed this year.

Air seasoning of aircraft woods.—The results of this investigation, which has been under way for three seasons, clearly show that the method of piling and handling the stock has a marked effect upon the rate of seasoning and upon the amount of degrade suffered. The investigation also showed that different species require different treatment and that the season of year during which the stock is first piled determines in a large measure what piling system should be used.

In this connection a survey of the seasoning practice at aircraft manufacturing plants will be made.

Effect of fungus infection on the mechanical properties of wood.—In the course of this investigation, which has been under way for a number of years, approximately 7,200 mechanical tests and 15,000 culture tests have been made. Reports have been prepared on the effect of yellow stain on the mechanical properties of white oak and on the relation of color and toughness strength of white ash. The data obtained from studies of Sitka spruce and Douglas fir are available in preliminary form only. The data that have been obtained will be carefully analyzed before any additional tests are made.

Cause and detection of brashness of wood.—It is known that brashness and low shock-resisting ability are quite generally found in specimens of low specific gravity. Occasionally, however, pieces with acceptable specific gravity which are apparently sound are weak and brash. The need of some means of detecting such weakness by inspection is obvious. In the study of spruce it has been found that compression failures are not infrequently the cause of low toughness values. A thorough analysis will be made of this spruce material which is now being studied to determine, if possible, the cause of brashness.

SUBCOMMITTEE ON COVERINGS, DOPES, AND PROTECTIVE COATINGS

Gas-cell fabrics.—At the Bureau of Standards extensive investigations have been conducted in the development of experimental gas-cell fabrics for rigid airships. Of the many varied types of fabrics which have been investigated, three have been selected because of their great promise of yielding suitable gas-cell material, and these are being developed for this purpose. Samples of one of these three type fabrics have already been subjected to outdoor exposure, under outer cover cloth, for a period of over 12 months, while samples of a second have been exposed, under similar conditions, for over 10 months. In both cases the exposures were made during periods including the coldest winter and the hottest summer months, and in neither case was there measurable increase in permeability or great decrease in breaking strength after such exposure. Samples of the third type of fabric mentioned above are now being prepared for exposure tests. While the result of such tests can not be definitely predicted in advance, it is believed that this last type of fabric will prove to be the best of the fabrics which have been investigated, and will, when fully developed, be the most satisfactory substitute for the goldbeater's skin fabric now used in rigid airships. All three of the fabrics mentioned above are light in weight, flexible, and have permeabilities well under the limit of 1 liter per square meter per 24 hours. Other types of fabrics are now under investigation. The study of these, however, has not progressed far enough to warrant any statement as to their probable value.

Other miscellaneous problems worked out at the Institute of Paint and Varnish Research are briefly outlined below.

Coatings for gas cells.—It has been suggested that 6 to 8 per cent of aluminum powder be mixed with the spar varnish which is used to coat the outside of gas cells for airships. As the solar radiation of a fabric exposed to the sun is reduced about 40 per cent, it is probable that aluminum powder in the varnish for gas cells would be advantageous, as the bags and the gas they contain would increase in temperature less rapidly.

Coatings for duralumin to prevent corrosion.—A coating for duralumin produced by anodic deposit of the metal in a plating bath has been developed. The deposit is aluminum oxide, which is a distinct protection. The process is patented. Usually the articles are lacquered after the plated coating is applied.

As there is some danger of weakening the metal in the plating bath, it seems preferable to give two coats of Navy aluminum spar varnish, which is cheaper and seems to give as good protection.

At the suggestion of the Bureau of Aeronautics, duralumin sheets such as are used for airplane pontoons were alternately exposed to sea water and to air under tropical conditions. A coating has been developed which will prevent the growth of barnacles and be durable in air. It is made from plastic resin, coal tar, and toxic poisons. The results were very satisfactory although the conditions were very severe.

Excellent results have been obtained at the Naval Aircraft Factory by using an inexpensive bituminous paint for floats and hulls. If the surfaces are inclosed this paint probably gives the best protection against underwater corrosion. The disadvantage is that, as a thick coat must be applied, the coating is heavy. This paint can be greatly improved by the addition of 10 to 20 per cent of asbestine, a crystalline pigment, showing a rod-like structure under the microscope. The rods act much like reinforcing rods in concrete. On exposure to sunlight, unfortunately, this paint breaks down rapidly, showing an alligator-skin surface. The bituminous compound flakes and powders rapidly.

Cotton flannel is often used as a water stop between sheets of duralumin. If the flannel is impregnated with asphaltum, gasoline will dissolve it. It is preferable to impregnate the flannel with a 3-pound cut of shellac in alcohol, which will not dissolve.

Coatings for magnesium to prevent corrosion.—Preliminary exposure tests of magnesium sheets have been made. It was found that uncoated magnesium sheets corrode slightly and the color becomes dark if exposed so that moisture dries off but that they become deeply pitted in six months if the surface does not dry off. Sheets coated with silicate of soda resist corrosion better than the uncoated sheets although if the surface does not dry off, they do corrode.

Two coats of aluminum spar varnish apparently give perfect protection. This coating was the lightest in weight. Doped coatings were very unsatisfactory. Six-month tests showed about equal corrosion in magnesium and in steel sheets.

Airplane dopes and paints.—Wing surfaces of airplane cotton were given one coat of dope and one coat of viscose. The surfaces were very taut. After exposure for six months some of the surfaces showed scaling of the viscose; others were in very good condition, particularly those having an outer coating of spar varnish. Surfaces coated with viscose are very much smoother than the usual doped surface. They should, therefore, offer less wind resistance. Paints containing aluminum and zinc powder for use on wing surfaces should have the powder mixed with the spar varnish just before the paint is applied. If this is done, the colors are much brighter than they are if the powder is mixed with the varnish and allowed to stand for months before the varnish is used.

It has been found that the scaling of the flag colors, which has been found in service, can be prevented by using lightweight pigments of high opacity instead of the heavy pigments of low opacity which have often been used.

Extensive tests are under way at Washington and at Pensacola with 200 frames covered with airplane cotton and doped with different schemes. Lightweight and permanent tautness and strength are sought.

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PART IV

TECHNICAL PUBLICATIONS OF THE COMMITTEE

On recommendation of the committee on publications and intelligence, the National Advisory Committee for Aeronautics has authorized the publication of 23 technical reports during the past year. The reports cover a wide range of subjects on which research has been conducted under the cognizance of the various subcommittees, each report having been approved by the subcommittee concerned and recommended to the executive committee for publication. The technical reports presented represent fundamental research in aeronautics carried on at different aeronautical laboratories in this country, including the Langley Memorial Aeronautical Laboratory, the aerodynamical laboratory at the Washington Navy Yard, the Bureau of Standards, the Forest Products Laboratory, the Stanford University, and the Massachusetts Institute of Technology.

To make immediately available technical information on experimental and research problems, the National Advisory Committee for Aeronautics has authorized the issuance in mimeographed form of another series known as "Technical Notes" of which 23 have been issued during the past year.

In addition to issuing technical reports and technical notes the committee has authorized the issuance in mimeographed form of translations and reproductions of important technical articles of a miscellaneous character in a series known as "Technical Memorandums." In accordance with this authorization, the committee has issued 51 technical memorandums on subjects that were of immediate interest not only to research laboratories but also to airplane manufacturers.

Summaries of the 23 technical reports, and lists of the technical notes and technical memorandums prepared during the past year follow.

SUMMARIES OF TECHNICAL REPORTS

The first annual report of the National Advisory Committee for Aeronautics contained Technical Reports Nos. 1 to 7; the second annual report, Nos. 8 to 12; the third annual report, Nos. 13 to 23; the fourth annual report Nos. 24 to 50; the fifth annual report Nos. 51 to 82; the sixth annual report, Nos. 83 to 110; the seventh annual report, Nos. 111 to 132; the eighth annual report Nos. 133 to 158; the ninth annual report Nos. 159 to 185; the tenth annual report Nos. 186 to 209; and since the preparation of the tenth annual report the committee has authorized the publication of the following technical reports, Nos. 210 to 232:

Report No. 210, entitled "Inertia Factors of Ellipsoids for Use in Airship Design," by L. B. Tuckerman, Bureau of Standards.—This report is based on a study made by the writer as a member of the special committee on design of Army semirigid airship *RS-1* appointed by the National Advisory Committee for Aeronautics.

The increasing interest in airships has made the problem of the potential flow of a fluid about an ellipsoid of considerable practical importance. In 1833 George Green, in discussing the effect of the surrounding medium upon the period of a pendulum, derived three elliptic integrals, in terms of which practically all the characteristics of this type of motion can be expressed. The theory of this type of motion is very fully given by Horace Lamb in his "Hydrodynamics," and applications to the theory of airships by many other writers. Tables of the inertia coefficients derived from these integrals are available for the most important special cases. These tables are adequate for most purposes, but occasionally it is desirable to know the values of these integrals in other cases where tabulated values are not available. For this reason it seemed worth while to assemble a collection of formulæ which would enable them to be computed directly from standard tables of elliptic integrals, circular and hyperbolic functions and ogarithms without the need of intermediate transformations. Some of the formulæ for special cases (elliptic cylinder, prolate spheroid, oblate spheroid, etc.) have been published before, but the general forms and some special cases have not been found in previous publications.

Report No. 211, entitled "Water Model Tests for Semirigid Airships," by L. B. Tuckerman, Bureau of Standards.—The design of complicated structures often presents mathematical problems of extreme difficulty which are frequently insoluble. In many cases, however, the solution can be obtained by tests on suitable models. These model tests are becoming so important a part of the design of new engineering structures that their theory has become a necessary part of an engineer's knowledge.

For balloons and airships water models are used. These are models about 1/30 the size of the airship hung upside down and filled with water under pressure. The theory shows that the stresses in such a model are the same as in the actual airship.

In the design of the Army semirigid airship *RS-1* no satisfactory way was found to calculate the stresses in the keel due to the changing shape of the bag. For this purpose a water model with a flexible keel was built and tested. This paper gives the theory of the design, construction, and testing of such a water model.

Report No. 212, entitled "Stability Equations for Airship Hulls," by A. F. Zahm.—In the text are derived simple formulæ for determining, directly from the data of wind-tunnel tests of a model of an airship hull, what shall be the approximate character of oscillation, in pitch or yaw, of the full-scale airship when slightly disturbed from steady forward motion.

Report No. 213, entitled "A Résumé of the Advances in Theoretical Aeronautics Made by Max M. Munk," by Joseph S. Ames.—In order to apply profitably the mathematical methods of hydrodynamics to aeronautical problems, it is necessary to make certain simplifications in the physical conditions of the latter. To begin with, it is allowable in many problems, as Prandtl has so successfully shown, to treat the air as having constant density and as free of viscosity. But this is not sufficient. It is also necessary to specify certain shapes for the solid bodies whose motion through the air is discussed, shapes suggested by the actual solids—airships or airfoils—it is true, but so chosen that they lead to solvable problems.

In a valuable paper presented by Dr. Max M. Munk, of the National Advisory Committee for Aeronautics, Washington, to the Delft Conference in April, 1924, these necessary simplifying assumptions are discussed in detail. It is the purpose of the present paper to present in as simple a manner as possible some of the interesting results obtained by Doctor Munk's methods.

Report No. 214, entitled "Wing Spar Stress Charts and Wing Truss Proportions," by Edward P. Warner, Massachusetts Institute of Technology.—In order to simplify the calculation of beams continuous over three supports, a series of charts have been calculated giving the bending moments at all the critical points and the reactions at all supports for such members. Using these charts as a basis, calculations of equivalent bending moments, representing the total stresses acting in two bay-wing trusses of proportions varying over a wide range, have been determined, both with and without allowance for column effect. This leads finally to the determination of the best proportions for any particular truss or the best strut locations in any particular airplane. The ideal proportions are found to vary with the thickness of the wing section used, the aspect ratio, and the ratio of gap to chord.

Report No. 215, entitled "Air Forces, Moments, and Damping on Model of Fleet Airship *Shenandoah*," by A. F. Zahm, R. H. Smith, and F. A. Louden.—To furnish data for the design of the fleet airship *Shenandoah*, a model was made and tested in the 8 by 8 foot wind tunnel for wind forces, moments, and damping, under conditions described in this report. The results are given for air of standard density. $\rho = 0.00237$ slugs per cubic foot without VL/v correction, and with but a brief discussion of the aerodynamic design features of the airship. This account is a slightly revised form of Report No. 195, prepared for the Bureau of Aeronautics, July 22, 1922, and by it submitted for publication to the National Advisory Committee for Aeronautics.

Report No. 216, entitled "The Reduction of Airplane Flight Test Data to Standard Atmosphere Conditions," by Walter S. Diehl and E. P. Lesley.—This paper was prepared for the National Advisory Committee for Aeronautics in order to supply the need of practical methods of reducing observed performance to standard conditions with a minimum of labor. The first part gives a very simple approximate method of reducing performance in climb, and is particularly adapted to work not requiring extreme accuracy. The second part gives a somewhat more elaborate and more accurate method which is well suited to general flight test reduction. The third part gives the conventional method of calibrating air-speed indicators and reducing the indicated speeds to true air speeds. An appendix gives working tables and charts for the standard atmosphere.

Report No. 217, entitled "Preliminary Wing Model Tests in the Variable-Density Wind Tunnel of the National Advisory Committee for Aeronautics," by Max M. Munk.—This report contains the results of a series of tests with three wing models. By changing the section of one of the models and painting the surface of another, the number of models tested was increased to five. The tests were made in order to obtain some general information on the air forces on wing sections at a high Reynolds number and in particular to make sure that the Reynolds number is really the important factor, and not other things like the roughness of the surface and the sharpness of the trailing edge.

The few tests described in this report seem to indicate that the air forces at a high Reynolds number are not equivalent to respective air forces at a low Reynolds number (as in an ordinary atmospheric wind tunnel). The drag appears smaller at a high Reynolds number and the maximum lift is increased in some cases. The roughness of the surface and the sharpness of the trailing edge do not materially change the results, so that we feel confident that tests with systematic series of different wing sections will bring consistent results, important and highly useful to the designer.

Report No. 218, entitled "Standard Atmosphere—Tables and Data," by Walter S. Diehl.—This report is an extension of National Advisory Committee for Aeronautics Report No. 147. Detailed tables of pressures and densities are given for altitudes up to 20,000 meters and to 65,000 feet. In addition to the tables the various data pertaining to the standard atmosphere have been compiled in convenient form for ready reference.

Report No. 219, entitled "Some Aspects of the Comparison of Model and Full-Scale Tests," by D. W. Taylor.—This paper was delivered before the Royal Aeronautical Society as the 1925 Wilbur Wright Memorial Lecture. It treats the subject of scale effect from the standpoint of the engineer rather than the physicist, in that it shows what compromises are necessary to secure satisfactory engineering model test data and how these test data compare with full scale or with theoretical values. The paper consists essentially of three parts: (1) A brief exposition of the theory of dynamic similarity, (2) application of the theory to airplane model tests, illustrated by test data on airfoils from the National Advisory Committee for Aeronautics variable-density wind tunnel, and (3) application of the theory to propeller testing, illustrated by comparisons of model and full-scale results.

Report No. 220, entitled "Comparison of Tests on Airplane Propellers in Flight with Wind Tunnel Model Tests on Similar Forms," by W. F. Durand and E. P. Lesley.—The purpose of this investigation, which is the subject of this report, was to determine the performance, characteristics, and coefficients of full-sized air propellers in flight and to compare these results with those derived from wind-tunnel tests on reduced scale models of similar geometrical form.

The full-scale equipment comprised five propellers in combination with a VE-7 airplane and Wright E-4 engine. This part of the work was carried out at the Langley Memorial Aeronautical Laboratory, between May 1 and August 24, 1924, and was under the immediate charge of Mr. Lesley. The model or wind-tunnel part of the investigation was carried out at the aerodynamic laboratory of Stanford University and was under the immediate charge of Doctor Durand.

A comparison of the curves for full-scale results with those derived from the model tests shows that while the efficiencies realized in flight are close to those derived from model tests, both thrust developed and power absorbed in flight are from 6 to 10 per cent greater than would be expected from the results of model tests.

Report No. 221, entitled "Model Tests with a Systematic Series of 27 Wing Sections at Full Reynolds Number," by Max M. Munk and Elton W. Miller.—A systematic series of 27 wing sections, characterized by a small travel of the center of pressure, have been investigated at 20 atmospheres pressure in the variable-density wind tunnel of the National Advisory Committee for Aeronautics.

The results are consistent with each other, and indicate that for such "stable" sections a small effective camber, a small effective S-shape and a thickness of 8 to 12 per cent lead to good aerodynamic properties.

Report No. 222, entitled "Spray Penetration with a Simple Fuel Injection Nozzle," by Harold E. Miller and Edward G. Beardsley.—The tests covered by this report form a part of a general investigation of the application of fuel injection engine principles to aircraft engine service. The purpose of these tests was to obtain specific information on the rate of penetration of the spray from a simple injection nozzle, having a single orifice with a diameter of 0.015 inch when injecting into compressed gases.

The fuel was sprayed into a chamber fitted with glass walls and filled with nitrogen at various pressures. Special high-speed photographic apparatus, capable of taking a continuous series of 15 photographs at a rate of 4,000 per second, was used to record the development of single sprays. The effects of fuel pressures from 2,000 to 8,000 pounds per square inch and chamber pressures from atmospheric to 300 pounds per square inch on the rate of penetration and the development of the spray were studied.

The results have shown that the effects of both chamber and fuel pressures on penetration are so marked that the study of sprays by means of high-speed photography or its equivalent is necessary if the effects are to be appreciated sufficiently to enable rational analysis. It was found for these tests that the negative acceleration of the spray tip is approximately proportional to the 1.5 power of the instantaneous velocity of the spray tip.

Report No. 223, entitled "Pressure Distribution on the C–7 Airship," by J. W. Crowley, jr., and S. J. DeFrance.—This investigation was made by the National Advisory Committee for Aeronautics at the request of the Bureau of Aeronautics, Navy Department, for the purpose of determining the aerodynamic pressure distribution encountered on a "C" class airship in flight. It was conducted in two parts: (*a*) Tests on the tail surfaces in which the pressures at 201 points were measured and (*b*) tests on the envelope in which 190 points were used, both tests being made under as nearly identical flight conditions as possible, so that the results could be combined and the pressure distribution over the entire airship obtained.

The method of testing consisted of measuring the pressure by means of orifices located at the desired points connected to the tubes of a multiple liquid manometer. Simultaneous readings of all the pressures were obtained by photographing the manometer.

The results as presented in this report are mainly in tabular form and may be very briefly summarized as follows:

(1) The maximum local pressure encountered on a tail surface was 7.3 lb./sq. ft.

(2) The maximum total normal force on a complete tail surface was 352 pounds or a C_{NF} of 0.316 occurring on the bottom fin and rudder during a "reversal" of the rudder.

(3) The maximum moment of the tail surface forces about the center of buoyancy was 37,200 lb.-ft.

(4) The investigation of the envelope pressures, while showing the general distribution of pressure satisfactorily, is practically useless in the determination of total aerodynamic forces on the airship.

(5) It is concluded that the pressures set up by a bump are larger than those obtained in maneuvering.

Report No. 224, entitled "An Investigation of the Coefficient of Discharge of Liquids through Small Round Orifices," by W. F. Joachim.—The work covered by this report was undertaken in connection with a general investigation of fuel injection engine principles as applied to engines for aircraft propulsion, the specific purpose being to obtain information on the coefficient of discharge of small round orifices suitable for use as fuel injection nozzles.

Flow of the liquids tested under high pressure was obtained with an intensifier consisting of a 5-inch piston driving a direct connected 3/4-inch hydraulic plunger. The large piston was operated by compressed air and the time required for the displacement of a definite volume by the hydraulic plunger was measured with an electrically operated stop watch. The coefficients were determined as the ratio of the actual to the theoretical rate of flow where the theoretical flow was obtained by the usual simple formula for the discharge of liquids through orifices.

Values for the coefficient were determined for the more important conditions of engine service such as discharge under pressures up to 8,000 pounds per square inch, at temperatures between 80° and 180° F. and into air compressed to pressures up to 1,000 pounds per square inch. The results show that the coefficient ranges between 0.62 and 0.88 for the different test conditions between 1,000 and 8,000 pounds per square inch hydraulic pressure. At lower pressures the coefficient increases materially.

It is concluded that within the range of these tests and for hydraulic pressures above 1,000 pounds per square inch the coefficient does not change materially with pressure or temperature; that it depends considerably upon the liquid, decreases with increase in orifice size, and increases in the case of discharge into compressed air until the compressed-air pressure equals approximately three-tenths of the hydraulic pressure, beyond which pressure ratio it remains practically constant.

Report No. 225, entitled "The Air Forces on a Model of the Sperry Messenger Airplane Without Propeller," by Max M. Munk and Walter S. Diehl.—This is a report on a scale-effect research which was made in the variable-density wind tunnel of the National Advisory Committee for Aeronautics at the request of the Army Air Service. A $\frac{1}{10}$-scale model of the Sperry Messenger airplane with USA-5 wings was tested without a propeller at various Reynolds numbers up to the full scale value. Two series of tests were made: The first on the original model which was of the usual simplified construction, and the second on a modified model embodying a great amount of detail.

While this report is of a preliminary nature, the work has progressed far enough to show that the scale effect is almost entirely confined to the drag. In the tests so far conducted, the drag at any given angle of attack within the normal flying range is found to vary as $\left(\frac{VL}{v}\right)^n$. The exponent n is constant for any one angle of attack, and ranges from -0.045 at large angles of attack to -0.17 at small angles.

It was also found that the model should be geometrically similar to the full-scale airplane if the test data are to be directly applicable to full scale. If the condition of geometric similarity be fulfilled, the data obtained at a full-scale value of Reynolds number agree very closely with free-flight data. The variable-density wind tunnel, therefore, appears to be a very promising instrument for procuring test data free from scale effect. It is also admirably suited for studying the scale effect and obtaining information which is necessary in an interpretation of the results obtained in atmospheric wind tunnels at low values of Reynolds number.

Report No. 226, entitled "Characteristics of a Boat-Type Seaplane During Take-Off" by J. W. Crowley, jr., and K. M. Ronan.—This report, on the planing and get-away characteristics of the *F-5-L*, gives the results of the second of a series of take-off tests on three different seaplanes conducted by the National Advisory Committee for Aeronautics at the suggestion of the Bureau of Aeronautics, Navy Department. The single-float seaplane was the first tested and the twin-float seaplane is to be the third.

The characteristics of the boat type were found to be similar to the single float, the main difference being the increased sluggishness and the relatively larger planing resistance of the larger seaplane. At a water speed of 15 miles per hour the seaplane trims aft to about 12° and remains in this angular position while plowing. At 2.25 miles per hour the planing stage is started and the planing angle is immediately lowered to about 10°. As the velocity increases the longitudinal control becomes more effective but overcontrol will produce instability. At the get-away the range of angle of attack is 19° to 11° with velocities from the stalling speed through about 25 per cent of the speed range.

Report No. 227, entitled "The Variable-Density Wind Tunnel of the National Advisory Committee for Aeronautics," by Max M. Munk and Elton W. Miller.—This report contains an exact description of the new wind tunnel of the National Advisory Committee for Aeronautics. This is the first American type wind tunnel. It differs from ordinary wind tunnels by its being surrounded by a strong steel shell, 35 feet long and 15 feet in diameter. A compressor system is provided to fill this shell—and hence the entire wind tunnel—with air compressed to a density up to 25 times the ordinary atmospheric density.

It is demonstrated in the report that the increase of the air density makes up for a corresponding decrease in the scale of the model. Hence such American type wind tunnel is free from scale effect.

The report is illustrated by many drawings and photographs. All construction details are described, and many dimensions given.

The method of conducting tests is also described and some preliminary results given in the reports. So far, the tests have confirmed the chief feature of this wind tunnel—absence of scale effect.

Report No. 228, entitled "A Study of the Effect of a Diving Start on Airplane Speed," by Walter S. Diehl.—Equations for instantaneous velocity and distance flown are derived for an airplane which crosses the starting line of a speed course at a speed higher than that which can normally be maintained in horizontal flight. A specific case is assumed and calculations made for five initial velocities. Curves of velocity, average velocity, and distance flown are plotted against time for each case and analyzed. It is shown that the increase in average velocity due to a diving start may be very large for short-speed courses.

Report No. 229, entitled "Pressure Distribution over Thick, Tapered Airfoils, N. A. C. A. 81, U. S. A. 27 C Modified, and U. S. A. 35," by Elliott G. Reid.—At the request of the United States Army Air Service, the tests reported herein were conducted in the 5-foot atmospheric wind tunnel of the Langley Memorial Aeronautical Laboratory. The object was the measurement of pressures over three representative thick, tapered airfoils which are being used on existing or forthcoming Army airplanes. The results are presented in the form of pressure maps, cross-plan load and normal force coefficient curves and load contours.

The pressure distribution along the chord was found very similar to that for thin wings, but with a tendency toward greater negative pressures. The characteristics of the loading across the span of the U. S. A. 27 C Modified are inferior to those of the other two wings; in the latter the distribution is almost exactly elliptical throughout the usual range of flying angles.

The form of tip incorporated in these models is not completely satisfactory and a modification is recommended.

Report No. 230, entitled "Description and Laboratory Tests of a Roots Type Aircraft Engine Supercharger," by Marsden Ware.—This report describes a Roots type aircraft engine supercharger and presents the results of some tests made with it at the Langley Field laboratories of the National Advisory Committee for Aeronautics. The supercharger used in these tests was constructed largely of aluminum, weighed 88 pounds and was arranged to be operated from the rear of a standard aircraft engine at a speed of 1½ engine crankshaft speed. The rotors of the supercharger were cycloidal in form and were 11 inches long and 9½ inches in diameter. The displacement of the supercharger was 0.51 cubic feet of air per revolution of the rotors.

The supercharger was tested in the laboratory, independently and in combination with a Liberty-12 aircraft engine, under simulated altitude pressure conditions in order to obtain information on its operation and performance. During an investigation of the influence on the operation of the engine of various types of air-duct connections between the supercharger and the engine, the supercharger was subjected to considerable rough treatment, which it endured very well, so that it seems apparent that the supercharger could well endure service handling. By the proper portioning of the air-duct system the engine would operate at all speeds as smoothly and free from vibration as the normal engine.

From these tests it seems evident that the Roots blower compares favorably with other compressor types used as aircraft engine superchargers and that it has several features that make it particularly attractive for such use.

Report No. 231, entitled "Investigation of Turbulence in Wind Tunnels by a Study of the Flow about Cylinders," by H. L. Dryden and R. H. Heald.—With the assistance and cooperation of the National Advisory Committee for Aeronautics the Bureau of Standards has been engaged for the past year in an investigation of turbulence in wind tunnels, especially in so far as turbulence affects the results of measurements in different wind tunnels.

Two methods of making such studies are described in this report together with the results of the use in the 54-inch wind tunnel of the Bureau of Standards. The first method consists in measuring the drag of circular cylinders; the second in measuring the static pressure at some fixed point. Both methods show that the flow is not entirely free from irregularities.

Report No. 232, entitled "Fuels for High Compression Engines," by Stanwood W. Sparrow, Bureau of Standards.—From theoretical considerations one would expect an increase in power and thermal efficiency to result from increasing the compression ratio of an internal combustion engine. In reality it is upon the expansion ratio that the power and thermal efficiency depend, but since in conventional engines this is equal to the compression ratio, it is generally understood that a change in one ratio is accompanied by an equal change in the other. Tests over a wide range of compression ratios (extending to ratios as high as 14.1) have shown that ordinarily an increase in power and thermal efficiency is obtained as expected provided serious detonation or preignition does not result from the increase in ratio.

There are marked differences between fuels as regards the conditions under which they detonate or preignite. It follows that the employment of a high compression ratio is contingent upon securing a fuel which is suitable in its resistance to preignition and detonation and which at the same time possesses the other qualities essential to a satisfactory engine fuel.

This report is based very largely upon tests made at the Bureau of Standards during 1922, 1923, and 1924. It emphasizes the fact that there may be a difference between a fuel's ability to resist detonation and its ability to resist preignition. Although this report is primarily a general discussion of the properties essential to a satisfactory fuel for high-compression engines, certain fuels, benzol and alcohol in particular, are discussed in some detail.

LIST OF TECHNICAL NOTES ISSUED DURING THE PAST YEAR

No.

205. The Logarithmic Polar Curve—Its Theory and Application to the Predetermination of Airplane Performance. By Val Cronstedt.
206. Structural Weight of Aircraft as Affected by the System of Design. By Charles Ward Hall.
207. The Simplifying Assumptions, Reducing the Strict Application of Classical Hydrodynamics to Practical Aeronautical Computations. By Max M. Munk.
208. Tests on Duralumin Columns for Aircraft Construction. By John G. Lee.
209. Tests of Rotating Cylinders. By Elliott G. Reid.
210. The Testing of Aviation Engines under Approximate Altitude Conditions. By R. N. DuBois.
211. Aircraft Engine Design. By E. E. Wilson.
212. Simplified Propeller Design for Low-Powered Airplanes. By Fred E. Weick.
213. Discharge Characteristics of a High Speed Fuel Injection System. By Robertson Matthews.
214. Note on the Katzmayr Effect on Airfoil Drag. By Shatswell Ober.
215. The Calculation of Wing-Float Displacement in Single-Float Seaplanes. By Edward P. Warner.
216. The Velocity Distribution Caused by an Airplane at the Points of a Vertical Plane Containing the Span. By Max M. Munk.

No.

217. Note on the Air Forces on a Wing Caused by Pitching. By Max M. Munk.
218. The Estimation of Airplane Performance from Wind-Tunnel Tests on Conventional Airplane Models. By Edward P. Warner and Shatswell Ober.
219. The Comparison of Well-Known and New Wing Sections Tested in the Variable-Density Wind Tunnel. By George J. Higgins.
220. The Drift of an Aircraft Guided Toward its Destination by Directional Receiving of Radio Signals Transmitted from the Ground. By Edward P. Warner.
221. Model Tests on the Economy and Effectiveness of Helicopter Propellers. By Max M. Munk.
222. Air Flow Investigation for Location of Angle of Attack Head on a JN-4h Airplane. By R. G. Freeman.
223. Determination of the Lift and Drag Characteristics of an Airplane in Flight. By Maurice W. Green.
224. Pressure Distribution on the Nose of an Airship in Circling Flight. By Karl J. Fairbanks.
225. Propeller Scale Effect and Body Interference. By Fred E. Weick.
226. Wind-Tunnel Tests of Fuselages and Windshields. By Edward P. Warner.
227. Determination and Classification of the Aerodynamic Properties of Wing Sections. By Max M. Munk.

LIST OF TECHNICAL MEMORANDUMS ISSUED DURING THE PAST YEAR

281. Combustion of Liquid Fuels in Diesel Engine. By Otto Alt. Translated from "Zeitschrift des Vereines deutscher Ingenieure," July 14, 1923.
282. Results of Experiments with Slotted Wings. By G. Lachmann. Translated from "Zeitschrift für Flugtechnik und Motorluftschiffahrt," May 26, 1924.
283. Mooring Airships. By G. A. Crocco. Translated from "Note di Tecnica Aeronavale," 1923.
284. Duralumin, Its Properties and Uses. By R. Beck. Translated from "Zeitschrift für Metallkunde," April, 1924.
285. Calculation of the Hull and of the Car-Suspension Systems of Airships. By R. Verduzio. Translated from "Rendiconti Tecnici," March 15, 1924.
286. The American Airship *ZR-3*. By L. Dürr. Translated from "Zeitschrift des Vereines deutscher Ingenieure," May 31, 1924, Vol. 68, No. 22.
287. Effect of Altitude on Power of Aviation Engines. By Italo Raffaelli. Translated from "Rendiconti Tecnici," July 15, 1924.
288. Stieber Dynamometer Hub for Aircraft Propellers. By W. Stieber. Translated from "Zeitschrift für Flugtechnik und Motorluftschiffahrt," April 26, 1924.
289. Two-Seat Light Airplanes which Participated in Contest held at Lympne, England, Week of September 29, to Oct. 4, 1924. Taken from "Flight," September 25, October 2 and 9, and from "Aeroplane," September 24, October 1, 8, and 15, 1924. Compiled by N. A. C. A.
290. Aviation Engines in the Endurance Contest. By G. Lehr. Translated from "L'Aéronautique," July, 1924.
291. Measuring Vibration and Torque with the Oscillograph. By R. Elsasser. Translated from "Zeitschrift des Vereines deutscher Ingenieure," May 17, 1924.
292. The Aerodynamic Laboratory of the Belgian "Service Technique de L'Aéronautique." Translated from "Bulletin du Service Technique de L'Aéronautique," May, 1924.
293. Nomogram for Correcting Drag and Angle of Attack of an Airfoil Model in an Air Stream of Finite Diameter. Translated from Report A 58 of the "Rijks-Studiedienst voorde Luchtvaart," reprinted from "De Ingenieur," September 20, 1924.
294. Motive Power Required to Operate a Wind Tunnel. By S. Ziembinski. Translated from "L'Aérophile," August and September, 1924.
295. Hulls for Large Seaplanes. By Giulio Magaldi. Translated from "La Technique Aéronautique," October 15, 1924.

No.

296. Experimental Determination of Pressure Drop Caused by Wire Gauze in an Air Stream. Translated from Report A 77 of the "Rijks-Studiedienst voor de Luchtvaart," reprinted from "De Ingenieur," August 9, 1924.
297. Royal Aero Club Light Aeroplane Competition. By J. S. Buchanan. Paper read before the Royal Aeronautical Society, October 30, 1924.
298. Results of Recent Experiments with Slotted Wings. By G. Lachmann. Translated from "Zeitschrift für Flugtechnik und Motorluftschiffahrt," August 26 and September 26, 1924.
299. Determination of Ignition Points of Liquid Fuels Under Pressure. By J. Tausz and F. Schulte. Translated from "Zeitschrift des Vereines deutscher Ingenieure," May 31, 1924.
300. Pressure Distribution on Fuselage of Airplane Model. Translated from Report A 33 of the "Rijks-Studiedienst voor de Luchtvaart," Amsterdam, reprinted from "De Ingenieur," of January 26, 1924.
301. Light Airplanes of France, Germany, Italy, Belgium, Holland, Czechoslovakia and Lithuania. Compiled by the National Advisory Committee for Aeronautics.
302. Effect of Speed on Economy of Airship Traffic. By W. Bleistein. Translated from "Zeitschrift für Flugtechnik und Motorluftschiffahrt," October 28, December 13 and 27, 1924.
303. Pitot-Static Tubes for Determining the Velocity of Air. By H. Kumbruch. Translated from "Forschungsarbeiten aus dem Gebiete des Ingenieurwesens," 1921, No. 240.
304. Suggestions for Courses of Instruction in Aviation. By Professor Poeschel. Translated from "Luftfahrt," December 5, 1924.
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During the year 1924 the committee issued a bibliography of aeronautics for the years 1920 and 1921 in one volume, and also a bibliography for 1922. It had previously issued bibliographies for the years 1909 to 1916 and 1917 to 1919. Bibliographies for the years 1923 and 1924, which are now in the hands of the printer, will be issued in separate volumes and should be ready for distribution during the coming year. An annual bibliography will be published hereafter by the committee.

Citations of the publications of all nations are included in the language in which the publications originally appeared. The arrangement is in dictionary form, with author and subject entry, and one alphabetical arrangement. Detail in the matter of subject reference has been omitted on account of cost of presentation, but an attempt has been made to give sufficient cross reference to make possible the finding of items in special lines of research.

PART V

THE PRESENT STATUS OF AVIATION

THE PRESENT STATE OF TECHNICAL DEVELOPMENT

AERODYNAMICS.—Satisfactory progress has been made in the science of aerodynamics during the past year. It is gratifying to note that this progress not only includes the development of basic theories of air flow but also the practical applications of these theories. In the latter field the recent progress has been rapid and still further practical applications may confidently be expected. The most notable example of the recent adaptation of theory to practical problems is probably to be found in the Prandtl-Munk equations, which enable the drag of any system of wings to be calculated from monoplane-test data.

The progress which has been made in the technique and interpretation of wind-tunnel tests closely parallels that made in pure and applied theory. In particular, the limitations of the atmospheric wind tunnel, the corrections which must be applied for the interference between the model and the tunnel walls, the requirements which must be met in model construction, and the securing of full-scale data are problems which appear to have been successfully solved, and the solutions will have an important influence on wind-tunnel investigations in the future. One important result of wind-tunnel investigation has been the development of a number of remarkably efficient wing sections of adequate thickness for economical structures. It is desirable that this development continue substantially along the present course.

There has recently been made available through the various research laboratories and organizations a large volume of airplane propeller data obtained from systematic tests in which all of the major elements of design are treated. These tests determine the effects not only of blade interference, blade shape, camber, pitch-diameter ratio, etc., but also of interference between the propeller and objects in its slip stream. The knowledge of interference effects is of value to the propeller designer, since it enables him to obtain satisfactory results from a single design instead of following the cut-and-try methods involving from three to six designs. While the progress in propeller design has been rapid, there is considerable information yet to be obtained. This information is of such nature that it is best obtained from full-scale tests either in free flight or in a suitable wind tunnel. Considerable free-flight work has already been done and arrangements have been made to supply facilities for full-scale wind-tunnel tests.

A careful study of the present state of knowledge in aerodynamics discloses a number of lines along which future investigations must be carried out. The most important of these will be described briefly.

More knowledge must be obtained on the forces on an airplane in various maneuvers in order that an efficient structure may be designed to carry these loads. The distribution of the loading is particularly important. For example, free flight pressure distribution tests have shown the resultant forces to be substantially those used in design, but, owing to surprising irregularities in distribution, the local loadings sometimes are more than twice as great as the maximum values used in design. A large field for research lies along this line.

The subject of control of airplanes in flight is of primary importance, not only from the standpoint of adequate strength of the control surface, but also from the consideration of adequate control. Several cases of failure of control surfaces have occurred in flight during the past three years. Service operation and flight tests have revealed high local loadings in certain maneuvers on airplanes of the pursuit type. This knowledge is now being applied to current designs, but more information is required.

In regard to the inadequacy of control, the limitations imposed by the inherently indefinite nature of the problem make its solution difficult. It is difficult to define adequate control just as it is difficult to define controllability or maneuverability. Every pilot and every engineer can perhaps find a definition which answers his own requirements, but universal agreement can not be expected. However, the problem can be resolved into three general divisions, as follows:

(1) Control and design characteristics, that is, relations between control and the design characteristics such as the span, chord section, and arrangement of the wings, the location of the center of gravity, the size and location of tail surfaces, the size and shape of the fuselage, etc. Valuable work has been done along this line, but a thorough systematic research is needed.

(2) Controllability and maneuverability: Some airplanes are readily maneuvered into any desired position with very slight effort on the part of the pilot. Other airplanes differing but slightly in general appearance either can not be so maneuvered or else require considerable effort on the part of the pilot. A few of the factors which affect controllability and maneuverability are known, but more complete information is necessary unless the design of pursuit airplanes is to remain an art instead of developing into a science.

(3) Control at low speeds: This is a matter of vital importance for commercial aviation. The subject is now receiving concentrated attention abroad and considerable work has been done in this country. Recent progress has been of such a nature that several solutions now appear available. The goal of the engineer is, of course, to free the airplane entirely from the danger of a crash due to loss of control following a stall at low altitudes. Two methods of attack are available—one to prevent the stall, the other to provide adequate control of the airplane in the stalled condition.

The problem of wing or control surface flutter seems to have been satisfactorily solved through wind tunnel tests, both as to causes and as to prevention. The primary cause appears to be one of relative stiffness or flexibility, and by a suitable proportion of stiffness in any particular case, flutter may be prevented. However, its complete elimination is not to be expected until an exhaustive treatment is made available to designers who will take the necessary precautions in design.

Another subject of considerable importance is the limitations imposed on airplane performance by the design requirements. These limitations are not as widely known as they should be. Consequently, some designers may claim unreasonable performance for their designs because they have failed to take into consideration certain very important requirements, such as adequate structural strength and stiffness. A clear and complete statement of design requirements should be prepared for the information of all designers. Under the present arrangement most of the needed information is available but not in a convenient form.

AIRPLANE STRUCTURES.—*Trend of design.*—While neither the monoplane nor biplane has gained complete acceptance for any particular use during the past year, out of an increasingly clearer understanding of the relative advantages of the two types there has grown an increased tendency toward standardization. For high speed, either for racing or for pursuit airplanes, the biplane has steadily gained in favor until it dominates that field almost completely, notwithstanding the fact that a monoplane holds the world's record for straight-away speed. Structural difficulties with the monoplane, and particularly the danger of wing flutter, have been largely responsible for its decreased popularity where great speed range is desired. Experience seems to show that for general pursuit use, having regard to the importance of maneuverability and the minimum obstruction of the pilot's vision, a biplane with the lower wing considerably smaller than the upper has proven most successful.

The larger military airplanes are of the biplane type in most cases, partly because of the greater compactness of the biplane of a given area and weight. For naval service especially the last consideration is of vital importance.

For commercial service both monoplanes and biplanes are used, the latter having, in general, the advantage in maneuverability and in compactness of form, but suffering somewhat in aerodynamic efficiency by comparison with the single-wing type. Where speeds are low and efficiency is the primary requirement, as on the lines of central and western Europe, the monoplane controls the field. The monoplanes now in use are either of all-metal construction or fitted with wings covered with plywood.

In the light airplane the importance of efficiency is such that monoplanes and biplanes of very high aspect ratio have given the best results, the former being in the majority. Aspect ratios in this type of airplane, although well above the average for military machines, are, because of the importance of weight in the light airplane, much lower than had become common in glider construction. There is a general tendency to increase aspect ratios and use thicker airfoil sections in all types, and, except in England, the airfoil section having a maximum thickness of less than 0.09 of the chord has virtually disappeared.

Structural materials.—Metal construction of airplane wings has developed much less rapidly in America than in European countries. The practice of any nation in the design of military airplanes is largely governed by the nature of the materials readily available. In America, with large native spruce forests, wooden wing spars are used in most instances, although there is a steadily increasing interest in metal. In Great Britain steel is commonly employed, while in France, which has native resources for the production of aluminum, duralumin is almost universally employed for wings and fuselages. In Germany duralumin holds first place. Metal covering is little used outside of Germany, where it is universally used.

Fuselage construction is of metal in practically all cases because of its greater durability and better shock-absorbing qualities in case of a crash. In America, the Netherlands, and some of the smaller European countries fuselages are commonly constructed of steel tubes assembled by welding. British practice has also inclined toward steel tubes, but with assembly by pinned fittings, while most of the important continental manufacturers use duralumin, either in tubes or structual forms.

When metal is used in wing construction it may take the form of simple tubes, or, as is the common practice in Great Britain, the alloy steel of thin sheet may be rolled into somewhat complex forms and assembled into spars by riveting.

In landing-gear construction the outstanding development of the year in America has been the trial and rapid recognition of the value of the Oleo gear for shock absorption. Such gears reduce the liability to bouncing and at the same time increase the efficiency of shock absorption and the violence with which the airplane can be brought into contact with the ground without damage.

Small floats are still commonly made of wood, although duralumin is sometimes used. In flying-boat hulls, metal is steadily increasing in popularity, as it has been found that seaworthiness can be improved and the weight decreased. The *PN-9* flying boat which attempted the Hawaiian flight and had to cruise on the surface of the water for a number of days was fitted with a metal hull.

AIRCRAFT ENGINES.—Progress in aircraft engine development in this country is reflected in the fact that we now have proved engines in horsepowers ranging from 60 to 800. In the 60-horsepower class there is the Lawrance 3-cylinder radial "L" type. In the 200-horsepower class there are available the Wright model "E" water-cooled and the Wright model "J" air-cooled engines.

In the 300–400 horsepower field the Curtiss D-12, a 12-cylinder water-cooled engine, is in production and has given excellent performance, particularly in pursuit type airplanes. In the 400–500 horsepower field we have the Liberty, Packard 1A-1500, and Curtiss V-1400 engines. The two Packard 1A-1500 engines, with a gear ratio of 2 to 1, formed the power plants for the two *PN-9's* on the west coast-Hawaiian flight project. The Curtiss V-1400 engine was installed in the Pulitzer and Schneider cup racers. It gives every indication of being an extremely light and rugged engine.

The Wright model P-2 is now undergoing its dynamometer trials and is giving very satisfactory results. This is a 9-cylinder radial air-cooled engine of 450 horsepower at 1,800 revolutions per minute.

In the 500–600 horsepower class the 12-cylinder T–3 water-cooled engine meets the present requirements. This engine in the past year has been extensively used by the Navy in the three-purpose scout-torpedo-bombing airplane.

In the 600–800 horsepower class the Packard 1A–2500, a 12-cylinder water-cooled engine, has been flown in the PB–1, the Navy's west coast-Hawaiian airplane built by the Boeing Airplane Co., and in the latest Army and Navy bombers.

The Curtiss radial 400-horsepower 9-cylinder air-cooled engine is undergoing its tests at McCook Field. It gives great promise as a light-weight engine.

In the past year strides have been made in the matter of reliability and increased service between overhauls. A life between overhauls from two to four times as great as has been had in previous engines is now being obtained by the Wright model "J" and T–3 engines.

The aeromarine inertia starter has solved the starting problem and is in wide use in the Navy.

Airships.—During the past year there has been no new airship construction started in the United States. The technical development of airships has necessarily been confined to experimental investigations and research looking toward the improvement of existing airships.

With the completion of the *RS–1* semirigid airship, constructed for the Army Air Service by the Goodyear Tire & Rubber Co., the Army Air Service now has in its possession the largest semirigid airship in the world. A special subcommittee on the *RS–1* appointed by the National Advisory Committee for Aeronautics to report on the design and construction of semirigid type airships has made its report.

The technical development of airships lags considerably behind that of airplanes. There appear to be two reasons for this—the higher cost of airships, and the longer time taken for construction of airships.

The arrival in the United States of the *ZR–3*, now the U. S. S. *Los Angeles*, on October 15, 1924, after an epoch-making nonstop voyage of 5,600 miles in 81 hours, made the United States the possessor of two rigid type airships. The *Los Angeles* is a splendid example of modern airship design and construction.

In October, 1924, the U. S. S. *Shenandoah* successfully completed a 9,000-mile voyage from Lakehurst to Seattle and return. The airship remained away from her shed almost 20 days, basing on mooring masts, and during the period encountered unfavorable weather. The successful completion of the voyage proved the efficiency of the mooring masts, the soundness of construction of the *Shenandoah*, and the skill of her operators.

The loss of the *Shenandoah* on September 3, 1925, while on a voyage to the Middle West, was a severe blow to airship development. At this time the cause of the accident has not been determined, and it is hoped that the naval court of inquiry, after sifting all the evidence, will be able to determine the cause of the accident.

In the past few years the United States has led the world in experimental research with reference to improved design and operation of airships. The United States has now lost its position to Great Britain, which during the past year has actively pursued research and experimental problems and started the construction of two 5,000,000-cubic-feet rigid airships, one being built by the Government and one by a private manufacturer.

During the past year, however, progress has been made in determining the magnitude of stresses which may be encountered by airships in flight. In June, 1925, preliminary strain-gauge measurements were made on the *Los Angeles* in conjunction with the use of a rate-of-turn indicator. It is proposed to extend this work and in addition to conduct simultaneous pressure-distribution measurements in an effort to fix some relation between aerodynamic loads, magnitude of stress in important structural members, and acceleration in a horizontal or vertical plane as shown by a rate-of-turn indicator or sensitive accelerometer mounted in the airship's control cabin.

Further confirmation of existing design theories has been found through the extended tests carried out on a photoelastic model of the structure of a rigid airship at the Massachusetts Institute of Technology.

The behavior of duralumin and other light alloys under conditions likely to be encountered in airship practice has been investigated. Special study has been given to corrosion or deterioration of these alloys from various causes and possible means for preventing such corrosion or deterioration.

Water recovery apparatus has been improved in type, and with this improvement has come a considerable reduction in weight.

Study has been continued on substitute materials for the expensive goldbeater's skin heretofore considered necessary in gas-cell construction. One type of substitute fabric gave so much promise of success that the Navy Department constructed an experimental full-sized cell for test.

In accordance with legislation recently enacted, the Bureau of Mines, Department of Commerce, on July 1, 1925, took over the control of all matters affecting the conservation and production of helium, including operation of the helium production plant at Fort Worth, Tex., heretofore operated by the Navy Department. Attention has been given to lowering the cost of helium transportation and the Army Air Service and the Navy Department have each purchased a tank car for transporting helium. Each car will carry about 215,000 cubic feet of helium, and the saving in freight charges for a period of about two years will practically pay the cost of the tank car.

Experimental work has been continued toward the development of better means of handling large airships in and out of their sheds and while near the ground. The progress made promises the further development of methods which will materially reduce the number of men required for a handling crew. The success obtained with mooring airships both to stationary masts and to the floating mast on the U. S. S. *Patoka* has been gratifying.

AERONAUTICAL RESEARCH IN THE UNITED STATES

The National Advisory Committee for Aeronautics is charged by law with the supervision and direction of the scientific study of the problems of flight, with a view to their practical solution. The committee is authorized by law to direct and conduct research and experiment in aeronautics in such laboratories as may be placed under the direction of the committee. The membership of the committee and of its technical subcommittees is drawn from the governmental agencies concerned and from private life. The members of the main committee and of all subcommittees serve as such without compensation. It is a matter of gratification that since the creation of the committee no person has ever declined an invitation to serve as a member of either the main committee or one of its subcommittees. The committee has therefore been able to draw upon the best talent in America for the study of the fundamental problems of aeronautics, and in this way it has wielded an influence for the advancement of the science of aeronautics that could not have been secured in any other way. This has been done at the direct cost to the Government that involved only the traveling expenses of the members and the maintenance of a place for meetings.

The way the influence of the National Advisory Committee for Aeronautics is exerted is through discussion by each subcommittee of the new technical problems that are constantly arising in aeronautics, and the preparation of research programs from time to time, which programs invariably indicate the particular laboratory where each investigation recommended can be conducted to the best advantage of the Government. Investigations are assigned both to public and private laboratories in a way that makes for the most effective utilization of existing facilities and the most effective study of the problems. After approval by the main committee, estimates for the prosecution of the research programs are submitted to the Bureau of the Budget, and after the appropriations are made by Congress the investigations are pursued under the general cognizance of the executive committee. The more fundamental investigations, for which facilities do not exist elsewhere, are undertaken in the committee's own laboratory, known as the Langley Memorial Aeronautical Laboratory, located at Langley Field, Va., on a plot of ground set aside for the purpose by the Secretary of War, and on which the necessary buildings have been erected by the committee with appropriations provided for the purpose by the Congress. Other investigations are assigned, for example, to the Bureau of Standards, to the Forest Products Laboratory, to the Weather Bureau, to the Engineering Division of the Army Air Service, to the Navy, and to various universities having the requisite facilities for the proper study of the particular problems so assigned. This method has proved practical and successful in operation, and has led to the accomplishment of substantial results with a maximum of economy and efficiency.

The committee was created by Congress with the status of an independent Government establishment. It is a service organization, ministering to the needs of the Army, Navy, and Air Mail Service, as well as to the needs of commercial aviation. By virtue of its status, it has been able to initiate and conduct fundamental scientific investigations while at the same time responding to numerous requests from the War and Navy Departments for special investigations in aeronautics.

The committee enjoys many advantages which have contributed to its success. Chief among these may be mentioned the following:

1. The members of the National Advisory Committee and of its standing subcommittees serve without compensation, thus enabling the Government to obtain the services of men who would not otherwise be available for Government service.

2. The committee has the status of an independent Government establishment, and by virtue of such status reports directly to the President, receives its appropriations direct from Congress, and is enabled to initiate and conduct investigations of a truly scientific character, limited only by the funds available.

3. The research laboratories of the committee are located on a flying field, where all phases of the work, including flight operations, are controlled and actually performed by the committee's own technical staff, thus bringing theory and practice together under ideal conditions.

4. The committee has the confidence and support of the Army and Navy Air Services, and is able at all times to obtain any cooperation desired.

The committee has just completed its tenth full year of activity. While the satisfaction of useful service rendered is ample reward, the committee feels especially grateful to the President for his recognition of its services, expressed in his message to Congress transmitting the tenth annual report of the committee on December 8, 1924. It is therefore with pardonable pride that the committee quotes the following extract from that letter of President Coolidge addressed to the Congress of the United States:

> "* * * I concur in the committee's general recommendations, and agree that in the last analysis substantial progress in aviation is dependent upon the continuous prosecution of scientific research.
>
> "When the National Advisory Committee for Aeronautics was established by Congress in 1915, there was a deplorable lack of technical information on aeronautics in this country. In submitting this, the tenth annual report of the committee, I feel that it is appropriate to say a word of appreciation of the high-minded and patriotic services of the men who have faithfully served their country without compensation as members of this committee and of its subcommittees. Through this committee the talent of America has been marshaled in the scientific study of the problems of flight, with the result that to-day America occupies a position in the forefront of progressive nations in the technical development of aeronautics. The status of the committee as an independent Government establishment has largely made possible its success.
>
> CALVIN COOLIDGE."

RELATION OF AERONAUTICAL RESEARCH TO NATIONAL DEFENSE

The relation of aeronautical research to national defense is direct, and its relative importance is increasing. This is necessarily so, because every improvement in the performance of aircraft makes the probable rôle of aviation in warfare greater. As the relative importance of aviation increases, it becomes more and more desirable for America to achieve and maintain leadership. As leadership can not be attained in all respects, it becomes of the greatest importance for America to lead in technical development. For ultimate leadership in time of emergency the United States must depend on the results of continuous research and development.

The National Advisory Committee for Aeronautics therefore believes it to be its duty to emphasize the importance of scientific research as the most fundamental activity of the

Government in connection with the development of aeronautics. Closely associated with this is the problem of engineering development of aircraft to meet the special needs of the military and naval services.

While the committee is of the opinion that there should be no monoply of engineering development, either by the Government or by the industry, it believes that it is desirable, in order to secure the best results, that the actual users of military and naval aircraft should be in close touch with competent aeronautical engineers. As a practical proposition, this can be done only if there are such engineers in the Army and Navy Air Services who are in such close touch with the operators that the latter are able to offer to them constructive criticisms in regard to engineering problems. This would enable the aeronautical engineers of the industry to thoroughly understand the problems presented to them and would prevent them from wasting their energies in attempting to develop military types of airplanes which would not meet the requirements of the services.

Without attempting to be specific, the committee is of the opinion that the military and naval services should maintain aeronautical engineering divisions which should be charged primarily with the formulation of specifications of military aircraft, their characteristics and performance; with the critical examination and testing of designs and of aircraft offered by the industry; and with such experimental and development work as can be carried on by them most effectively and most economically.

THE GENERAL PROBLEM OF AERONAUTICAL ORGANIZATION

In its tenth annual report, for the year 1924, the National Advisory Committee for Aeronautics presented an outline of the organization and functions of the four governmental agencies directly concerned with the use or development of aeronautics—namely, the Army Air Service, the Naval Bureau of Aeronautics, the Air Mail Service, and the National Advisory Committee for Aeronautics.

During the past year, there have been two major investigations of the aeronautical situation—the first by the Congressional Select Committee of Inquiry into Operations of the United States Air Services, created by Resolution No. 192 of the House of Representatives (68th Cong., 1st sess.), of which Representative Florian Lampert, of Wisconsin, is chairman; the second by the special board appointed by President Coolidge on September 12, 1925, known as "The President's Aircraft Board," of which Mr. Dwight W. Morrow is chairman. The investigations of the two bodies referred to have gone deeply into all phases of aeronautical activity and governmental organization in aeronautics, including the major problems of the relation of aircraft to national defense; the organization, morale, and sufficiency of air personnel; the maintenance of the aircraft industry; the regulation and encouragement of commercial aviation; the development of airways, etc.

It is to be hoped that the recommendations of these two investigating bodies will receive careful consideration and lead to a settlement of the controversies in aeronautics that have existed since the war. The continued unrest in aeronautical circles has served to focus attention primarily on organization and administrative matters, but has also indirectly brought about a broader recognition of the increasing relative importance of aircraft for purposes of war and of commerce.

In the judgment of the National Advisory Committee for Aeronautics, however, the people of the United States are not so much concerned with the form and administration of the Government's activities in aeronautics as they are with the question as to whether practical and efficient results are being secured. It is only fair to say that the best results have not been obtained and will not be obtained as long as the personnel are disturbed and their attention distracted from their real duties. It is most desirable, therefore, that measures to improve the situation be formulated and carried into effect without delay. This will enable all who have the best interests of aeronautics at heart to cooperate and settle down to work in harmony with that full measure of devotion to duty which is necessary to bring about the greatest practicable development of aeronautics in America, for both military and commercial purposes.

PROGRESS IN COMMERCIAL AVIATION

The past year was notable as witnessing what may prove to be a real, substantial beginning of commercial aviation in America. The most encouraging factors were the initiative shown by private companies in establishing air lines and the relatively large number of responsible bidders for the carrying of air mail by contract with the Post Office Department. When it is realized that commercial aviation exists in European countries at this time only by virtue of the support of the various governments given through various plans of direct and indirect subsidies, it should be especially gratifying to all concerned with the advancement of aeronautics in this country to feel that the era of commercial aviation on a sound basis is about to dawn in America.

Although the National Advisory Committee for Aeronautics has long been of the opinion that commercial aviation must largely make its own way in America, it believes at the same time that the Government should aid commercial aviation in certain respects where Government aid is practicable and necessary. If, in recognition of this principle, commercial aviation can be successfully developed in America on a firm basis, its development will not be limited, whereas the development of European commercial aviation on a direct subsidy basis is necessarily limited by the nature and extent of the subsidies given. The committee believes that the American policy is sound and in the long run will be more effective in stimulating the substantial development of commercial aviation than will the European policy of direct subsidy.

In spite of this optimistic note, the facts of the situation that must be faced show a number and variety of problems requiring study and solution before commercial aviation can take its proper place in America. The most pressing needs requiring attention at this time are, first, legislation establishing the fundamental right of flight, creating a bureau of air navigation in the Department of Commerce for the regulation and licensing of aircraft, airports, and aviators, and for the establishment, maintenance, and lighting of adequate national airways, and providing for the necessary meteorological information; and, second, the improvement of airplane design and structure with a view primarily to making airplanes safer, more reliable, more controllable at low speeds incident to taking off and landing, and less expensive in initial cost, as well as in the cost of maintenance and operation. There should also be assistance from the other governmental agencies concerned, such as the Hydrographic Office, the Coast and Geodetic Survey, the Weather Bureau, the Lighthouse Service, and the Army and Navy Air Services.

To accomplish the first purpose, legislation is necessary. This has been repeatedly recommended by the National Advisory Committee for Aeronautics and has been indorsed in principle by all agencies of the Government concerned. This question is discussed at length in the report of the committee on civil aviation of the Department of Commerce and American Engineering Council. To accomplish the second purpose requires continuous prosecution of scientific research on the more fundamental problems of flight. This is the definite prescribed function of the National Advisory Committee for Aeronautics, and in the last analysis is necessarily the most fundamental activity in the whole field of aeronautics.

In the past the committee has devoted its attention primarily to the solution of problems arising from the development and use of military and naval types of airplanes and, to a lesser extent, airships. While the basic problems of aerodynamics and of design are the same for military and commercial airplanes, the service requirements as to performance, efficiency, and safety differ. Up to the present time airplanes used for commercial purposes in America have been largely adaptations of military types. This is best evidenced by the fact that the Air Mail Service is still using up war-time DH 4 airplanes with certain modifications.

The committee is of the opinion that with the advent of commercial aviation, a new series of problems peculiar to commercial aircraft will be presented. The committee has therefore decided to hold one or more meetings annually with the engineering representatives of aircraft manufacturing and operating industries, with a view to ascertaining definitely the problems deemed of most vital importance and to incorporating the same, as far as practicable, into the general research programs prepared by the committee.

THE PROBLEM OF THE AIRCRAFT INDUSTRY

In its tenth annual report, the committee outlined the relation of the aircraft industry to national defense, and emphasized the need of maintaining a satisfactory nucleus of an industry. This was defined as "a number of aircraft manufacturers distributed over the country, operating on a sound financial basis, and capable of rapid expansion to meet the Government's needs in an emergency." The committee presented certain definite suggestions of steps to be taken by the Government and by the industry to meet the situation that existed at that time. There has been substantial progress during the past year along the lines outlined by the committee, and it is believed that the condition of the industry and the relations of the Government to the industry have been much improved. The greatest single factor in bringing about this improved condition has been the increased volume of Government orders for aircraft, made possible by increased appropriations and contract authorizations for the purchase of aircraft. The present situation, on the whole, may be regarded as more satisfactory at this time, and as offering promise of further improvement.

THE AIRSHIP PROBLEM

Airships are of three types: Rigid, semirigid, and nonrigid. The value of airships for military or commercial purposes has not as yet been conclusively demonstrated. It can not be said, however, that they are without value, nor that they have no further possibilities than have already been demonstrated. The fact of the matter is that all types of airships are in the experimental stage of development. The recent regrettable loss of the rigid airship *Shenandoah* has been urged as a reason for the Government's abandoning airship development, or at least rigid airship development, on the theory that rigid airships never will be practicable.

The committee fully appreciates the seriousness of the airship situation and believes that despite all that has been done in many countries to develop airships, they are still rather delicate structures. The conclusions of the naval court of inquiry as to the causes for the destruction of the *Shenandoah* have not yet been made public. Regardless, however, of the actual technical causes, the committee is of the opinion that it would be a serious error at this time to adopt a policy of merely marking time in the development of airships. In the judgment of the committee, the time has come to decide to do one of two things, viz, either to carry on with the development of airships or to stop altogether.

The development of rigid airships in America for military and naval purposes has, by joint agreement between the War and Navy Departments, been entrusted to the Navy. The question of continuing their development, however, is not altogether a war problem, for airships of all types have probable applications also for commercial purposes. The question, therefore, whether the Navy should continue with the development of rigid airships at this time should not be determined solely upon considerations of their probable naval usefulness. The Army is directly concerned and the commercial development of airships in America may be said to be also at stake. The problem is therefore a national one. Viewed as such, the Navy becomes, in a peculiar sense, the agent of the whole people in the development of rigid airships. In the last analysis, however, it is for the Congress to determine America's policy with regard to continuing the development of airships. As between the two alternatives of carrying on or stopping altogether, the National Advisory Committee for Aeronautics, after careful consideration of the matter, is of the opinion that the development of airships should be continued.

SUMMARY

There has been continued gratifying progress in the technical development of aircraft. Performance and reliability have increased. The committee's program of research for the coming year promises to add substantially to the store of technical knowledge. There is nothing in sight at this time to indicate the probability of the discovery of a revolutionary principle contributing any great or sudden improvement in aircraft. While progress must be gradual, there is every reason to believe that there will be steady improvement in the performance, efficiency, reliability, and safety of aircraft.

Aviation has become more generally recognized as a weapon indispensable to war operations and as an instrument that gives promise of taking its place in the immediate future in the commercial life of the Nation.

During the past year alone there were three investigations of the aircraft situation. A special committee of the House of Representatives known as the "Lampert Committee," and a special board appointed by President Coolidge known as "The President's Aircraft Board," inquired into all details of the aircraft situation and the aeronautical organization of the Government. A third investigation, limited to civil and commercial aviation, was made by a special committee on civil aviation of the Department of Commerce and American Engineering Council. The recommendations of these bodies should serve to clarify the public mind and to focus attention on the major problems requiring immediate solution. Measures to meet the situation should be formulated and carried into effect without delay. In this connection the National Advisory Committee for Aeronautics reiterates its recommendations of previous years for the creation of a bureau of air navigation in the Department of Commerce to regulate and ncourage commercial aviation.

The state of the aircraft industry is gradually improving. The most substantial factors in improving the situation during the past year were the increase in appropriations and contract authorizations for the purchase of aircraft by the War and Navy Departments and the increasingly close liaison between the industry and the Government engineers. With sustained Government patronage on a continuous production basis and with the prospect of a growing commercial demand for aircraft, the condition of the aircraft industry will steadily improve.

Air mail service is no longer a novelty. It is passing out of the experimental stage and becoming a necessity in the daily business life of the Nation. It has reached the point where it has become practicable for private firms to carry air mail under contracts with the Post Office Department. Air transportation of the mails should therefore be extended gradually to meet the requirements of the people in all parts of the country.

CONCLUSION

The committee is of the opinion that America is at least abreast of other progressive nations in the technical development of aircraft for military purposes. The committee is grateful to the President and to the Congress for the support that has been given to scientific research in aeronautics. The committee feels that the continuous and systematic study and investigation of the basic problems of flight is the most fundamental activity of the Government in connection with the development of aeronautics and that the continuance of this work will serve to keep America at least abreast of other progressive nations in the technical development of aircraft for all purposes.

Respectfully submitted.

National Advisory Committee for Aeronautics,
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